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INVESTIGATION OF ACTUAL CONDITIONS
IN INTERNATIONAL R&D STRUCTURE

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[Text] **Introduction**

This investigative report is a compilation of the results of the "Research Study on Actual Conditions in International Structure of Research and Development," an investigation that the Science and Technology Agency's S&T Policy Bureau commissioned us to do in FY 1988 with Coordination Funds for the Promotion of Science and Technology. Based on the results of a two-year-long research study, this is a final report that comprehensively examines the international state of R&D affairs.

The deepening of mutual international relationships that center on scientific and technical R&D is becoming a situation where the development of those activities goes beyond national borders. Businesses of all countries are actively moving ahead with the development of R&D strongpoints abroad. In research organizations and higher-education organizations, too, the international exchange of researchers and scientific and technical information, international joint research, and other such cooperative activities are becoming more vigorous. In recent years, this international expansion of R&D activities has not been confined to the advanced nations of Japan, the U.S., and Europe. It is starting to have an important significance for developing countries, too, whose R&D activities have become vigorous as a result of technology transfer and economic support from the advanced countries.

Out of those R&D activities that turn into competitive and cooperative relationships, Japan is being asked to make contributions to the international society that correspond to its level of technology. For Japan, adequately grasping the actual

state of the interrelationships of each country's R&D activities is becoming necessary as a basis from which to make appropriate, effective S&T policies for the purpose of actively developing its R&D activities.

Based on this kind of recognition, our research study organizes and analyzes the statistics on R&D activities in five advanced countries (Japan, the U.S., West Germany, the U.K., and France) and in NIES and ASEAN countries, and then compares each of the countries. It also investigates the actual state of Japanese businesses' overseas R&D activities and examines the problems surrounding international R&D activities.

We hope that this report will be useful as a basis for Japan's future S&T policies.

Finally, we would like to again thank the gentelemen of the Research Committee and the many experts involved in this research study for their guidance and cooperation.

2 March 1990

Future Engineering Research Institute, an incorporated foundation

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I. Purpose of the Research Study and Summary of Results

1 Research Study Aims and Methods

1-1 Research Study Aims

Interlinked with the internationalization of economic activities, S&T activities have also reached a state in which their development goes beyond national borders.

Until now, three poles--Japan, the United States, and Europe--were at the center of any discussions about the state of R&D affairs that form the background of S&T activities. In contrast, S&T activities in developing countries are also becoming activated by grants and transfer of technology, economic aid, and other assistance from developed countries, assistance that started with Japan; in recent years the NIES (Newly Industrializing Economies) and ASEAN (Association of South East Asian Nations) countries are also continuing to take on an important role in the international environmental framework.

Given these circumstances, international cooperation and competition in R&D activities is becoming more of a reality, not only among advanced countries but including developing countries as well, and Japan too must promptly cope with the situation.

Therefore, in order to bring out the actual interrelationship between R&D activities of Japan, the United States, Europe and the NIES and ASEAN countries--clarification needed for Japan's government S&T policy studies--we will examine the actual international structure of R&D activities and the historical, industrial, and economic factors in that background; this investigation will give a grasp of analyses of each countries' R&D-related statistics and the state of domestic and foreign R&D activities of Japanese firms.

1-2 Survey Methods

(1) Survey of documentation

As basic materials for proceeding with this research study, we made a general outline of the results of major research studies on the internationalization of R&D activities, and organized the information with regard to what has up to now been clarified and what kind of subjects are remaining.

(2) Analyses of statistical figures

As basic tasks for revealing the international R&D structure, we made a database that covers about 100 series of indicators

relating to R&D activities of the United States, West Germany, France, the United Kingdom, and Japan.

In addition, as far as possible we supplemented NIES and ASEAN countries' statistics and U.N. statistics with the major economic indicators and indicators relating to R&D activities of NIES and ASEAN countries, and conducted comparative analyses in connection with the interrelationship of R&D activities among advanced countries--Japan, the United States, and Europe--and among developing countries--represented by ASEAN countries--and Japan, the United States, and Europe.

Furthermore, we conducted comparative analyses on the state of implementation of R&D activities overseas.

(3) Statistical searches using databases

In connection with the numbers of research paper announcements, for which in R&D-related statistics too there is not enough data, we used major bibliographic databases to conduct statistical searches and then analyzed the trends in each country. With Japan, the United States, West Germany, France, and the United Kingdom as the countries whose data we searched, we conducted comparative analyses that centered on changes in the main body of R&D in each country with respect to the major leading-edge S&T fields: 1) computer science, 2) the life sciences, and 3) superconducting materials.

(4) Investigations involving overseas hearings

As a case study of European R&D activities in a leading-edge S&T domain, we listened to the ideas of and collected data from public and private sector research organizations of countries such as France, West Germany, and Spain, for the purpose of getting a grasp on R&D trends in the field of aerospace.

Also, in order to understand R&D trends in ASEAN countries, we conducted investigations that involved listening to the ideas of S&T-related government organizations of Thailand and Indonesia, as representative examples.

1-3 Organization of the Research Study

In carrying out this research study, we organized a research committee. Its members are given below.

Research Committee

Chairman	Yujiro Hayashi	Vice-director of the Future Engineering Research Institute (an incorporated foundation)
Members	Masaru Sato	Professor at the Economics Department of Chuo University
	Zenichiro Nagara	Director of the Institute for Physical and Chemical Research (RIKEN)
	Akio Makijima	Professor, Engineering Department of Tokyo University
	Satoshi Goto	Deputy-chief manager of NEC's C&C Information Research Institute
	Hiroshige Sato	Assistant professor, Business Administration Dept. of Hosei University
	Moriiku Kuninori	Chief researcher, Bank of Japan's Plant and Equipment Investments Research Institute
	Yoichi Ito	Deputy of research at the Research Development Corporation of Japan's General Affairs Division, Policy Research Office
	Makiyuki Yokoyama	Researcher at the Society of S&T and Economics (a corporation)

Future Engineering Research Institute

Toshio Nishizawa	Chief researcher (research supervisor)
Takanori Maema	Researcher
Akinari Nagata	Researcher
Takashi Kikuda	Researcher
Yumiko Aibara	Researcher

2 Summary of Findings

2-1 International Comparison of R&D Strength

(1) Viewpoint towards the analysis

In this research study, analysis of the international structure of R&D involved taking a global, bird's-eye view of R&D strength and examining the changes in the mutual relationships among geographic or national growth processes and the primary factors for the growth and fluctuation of that R&D strength. Then, defining R&D strength as the power to bring forth scientific knowledge and technology, we subdivided and set up the following viewpoints for assessing R&D strength:

(a) Relative superiority of the level of R&D strength
(b) Basic potential strength for R&D

We established the group of indicators in Table 1 along the lines of these viewpoints.

Table 1. Views of international comparative analyses of R&D strength

Standpoint of comparative assessment	Character of assessment indicator	Sub-division of assessment indicator	Items of assessment indicator
(A) Relative superiority of R&D strength standards	R&D results group	Intellectual productivity	Theses, patents
		Materialistic productivity	GNP, manufactured products and high-tech trade, technology trade, direct invest-ments overseas
(B) Basic potential strength for R&D	R&D investments group	R&D resources	R&D funds, R&D personnel
		Research support environment	Policies, organizations and systems, society's lifestyle base, education

(2) Comparison of relative superiority of R&D strength standards of advanced countries

When looking at the changes over a 20-year interval in shares of of industrial and high-tech product exports, Japan's sudden increases stand out against the stagnation of the U.S. and the European countries. It follows that Japan's growth is remarkable, and the process of Japan's development is seen in its R&D and products and manufacturing technology.

Looking at R&D strength standards from the trends in patent applications filed in foreign countries and patent applications filed by foreigners, Japan outrivals the U.S. and Europe in the increased percentage of both the number of patent applications filed in foreign countries and the number of applications filed by foreigners. While it may be gathered that Japan's R&D strength is improving in terms of global standards, at the same time competition among Japan, the U.S., and Europe in economic and technology development activities is suggested.

Although Japan holds less than a one-tenth share of technology exports in the five leading countries, that amount increased by over tenfold in comparison with 1970. Also, the degree to which Japan relies on technology imports has been steadily decreasing, indicating another change that differentiates it from the U.S. and Europe.

On the other hand, from yearly data on the number of research paper announcements it can be seen that the R&D strength of European universities and other such academies, which boast of a long tradition, is waning; the strength of the U.S. is increasing and Japan is following close behind.

(3) Advanced countries' base potential strength

The relative diminishment of the U.S.'s position as the "world's R&D center" can be read from comparisons of research expenditures and research personnel.

When comparing the shares of the numbers of Japanese and U.S. researchers, in a full-time trial conversion of the number of Japanese researchers, including those in the humanities and social sciences, the number of researchers per million population was nearly equal to that of the U.S.

Looking at the research expenditures per researcher by organization, the scale of expenditures for research organizations was characteristically large in Japan. However, research expenditures at universities in Japan were in contrast

lower than those in the U.S., West Germany, and France. This hints at structural problems in Japan's domestic R&D.

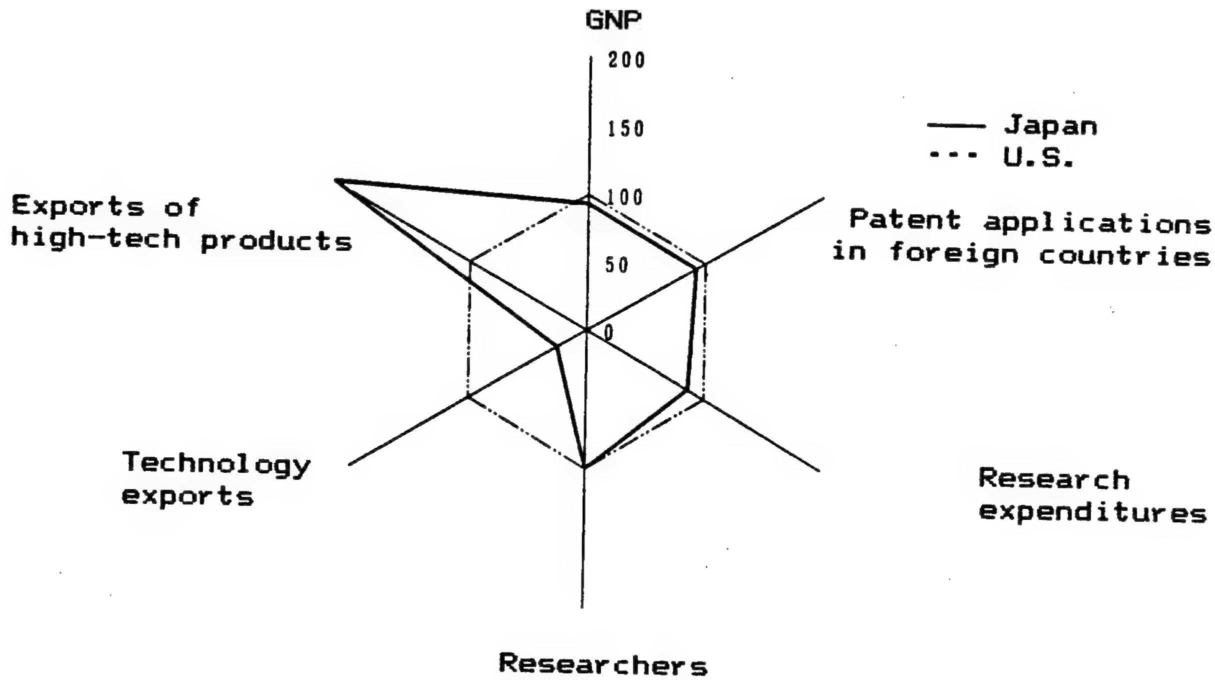
(4) Overall comparison of Japanese and U.S. R&D strength

From comparisons of R&D strength, the relative diminishment of the U.S. position and the growth of Japan can be seen as the distinctive state of affairs. Japan's change points to an alteration that can also be said to be unique among the advanced countries of Japan, the U.S., and Europe.

When comparing GNP, patent applications in foreign countries, exports of high-tech products, technology exports, research expenditures, and research personnel in terms of per-million-population-scale percentages, the strengths of Japan and the U.S. with respect to GNP and patent applications in foreign countries have very recently become nearly the same level; in research expenditures and research personnel, they have nearly the same base potential strength (Figure 1). Japan's trade in high-tech products is much greater than that of the U.S. On the other hand, the U.S. surpasses Japan by far in technology trade.

This suggests the existence of structural problems that affect the magnitude of the past and present timewise accumulation and flow.

Figure 1. Japan-U.S. Per-Million-Population-Scale Comparisons



* U.S. indexed as 100
* Patent applications in foreign countries includes numbers from Economic Policy Committee
* Both research expenditures and research personnel are only for the natural sciences in Japan; includes the humanities and social sciences in the U.S.
* High-tech products depend on OECD definitions

Data: Japan — Monthly Report of Population Statistics from the Management and Coordination Agency; Annual Report of National Economic Figures from the Economic Planning Agency; Patent Office Annual Report; S&T Research Survey from the Management and Coordination Agency; Monthly Report of International Revenues and Expenditures Statistics from the Bank of Japan; "Science and Engineering Indicators - 1989"

U.S. — World Population Yearbook from the United Nations; Patent Office Annual Report; NSF statistics; "International Financial Statistics" of the IMF; "Survey of Current Business" from the DOC; "Science and Engineering Indicators - 1989"

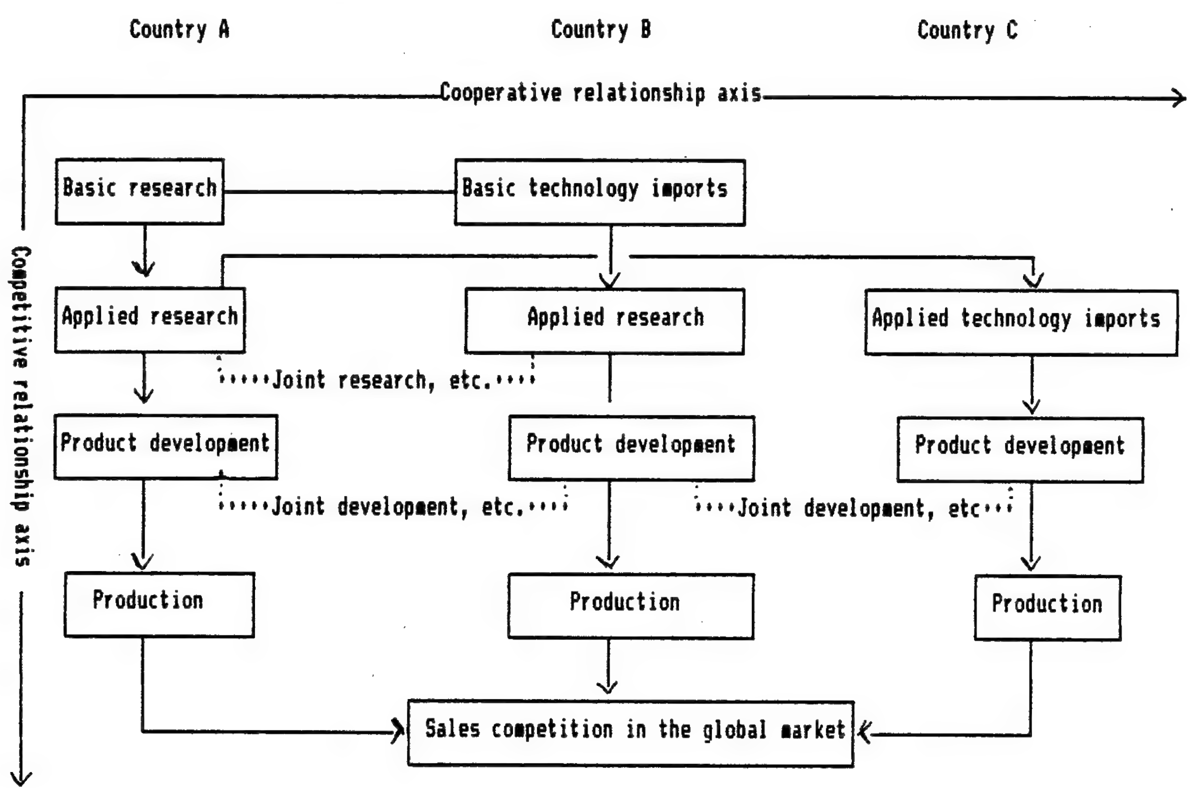
2-2 Growth Processes and Interrelationships of R&D Powers

(1) International relationship model

We hypothesized a model similar to Figure 2 to show the internationally competitive and cooperative relationships of R&D powers.

That is, Country A is a leading country type that independently implemented a series of R&D processes and holds a position as an R&D leader. The Country B type depends on technology transfer from primarily Country A for its basic technology and concentrates its efforts on the development of applied technology. Then in this process it improves the driving force of its basic research and technology. The Country C type depends on technology transfer from both Countries A and B for its applied technology and its development as well, and is working towards forming the foundation of its technological development strength.

Figure 2. Structure of International Competition and Cooperation in R&D Activities



Economically, there is a competitive relationship among these types of countries, and, when the situation is such that R&D results become international public property, the possibility of implementing joint research on up to joint development is not excluded.

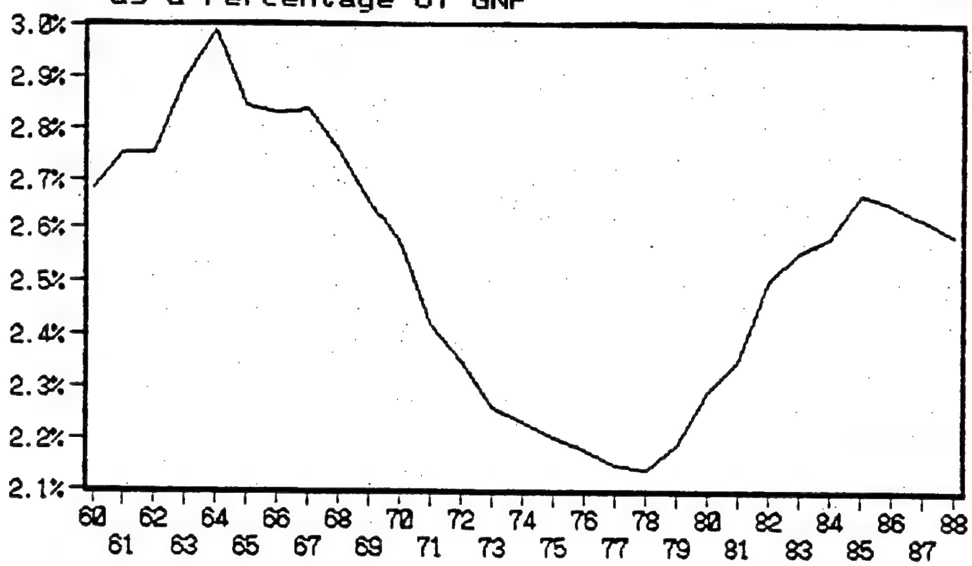
This kind of international relationship model is strictly a hypothetical model. However, supposing that, for example, Country A is the U.S., Country B is Japan, and Country C is Korea (Thailand), it can probably be presented as the framework for a relatively effective explanatory summary.

(2) U.S. tracks

From the aspect of government policy, the development of U.S. R&D strength passes through three transitional periods. The first period of transition was when, in the midst of an intensifying cold war relationship with the Soviet Union after World War II, the Soviet Union was the first to launch a satellite. The second policy transition arose from the improvements made in "big science" by enormous investments of funds. The third transition is thought to have started during the Carter administration, which again shifted towards strengthening government support of R&D activities.

The effects of the U.S. policy transitions on the overall level of R&D activities is obvious in the R&D expenditures as a percentage of GNP that are shown in Figure 3. Until about the end of the 1960's, the percentage of GNP that went for research was at a high level, about 2.8%, but during the 1970's it shows a consistent downward trend; during the 1980's, it is again rising considerably. Although the percentage dropped somewhat after 1986, it is still at a higher level than that of the late 1970's.

Figure 3. Changes in Growth Rates of U.S. Research Expenditures as a Percentage of GNP



As shown above, a striking feature is seen in the fact that government S&T policies hold a great deal of weight in U.S. R&D activities. Looking at the participation of the U.S. government in R&D activities, the federal government's percentage of the burden of total R&D expenditures was at about a 47% level in 1984. Although the government's percentage of the burden is tending to decline over the long term, the 47% figure is still a high level in comparison with other advanced countries. Furthermore, with a level of 25% of these expenditures used within the federal government and the rest disbursed to businesses, universities, research organizations, and other groups as subsidies, commission fees, etc., it can be seen how the U.S. government's S&T policies fit into a structure that bears the role of leadership in the U.S. Another point about the structure of government expenditures for R&D costs that should be noted is that the government's percentage of the burden of basic research costs is remarkably high. In particular, it is pointed out that aid through the U.S. National Science Foundation and the National Institute of Health has come to play an important role in the government's support for basic research.

The scientific knowledge and the technology that is brought forth from this aid is disseminated throughout the world as theses and patents, the exchange of scientists, etc., and it has come to stimulate and activate the world's R&D.

On the other hand, in understanding the growth process of R&D in the United States, an unfathomable point that goes along with the government's contribution of R&D policies is the multi-national development in the private sector. Development of the U.S. multi-national private sector and, through its overseas affiliates, the transfer of technology from the United States played tremendous roles in post-World-War-II recovery and in the industrial rebirth and technological development of Europe and then Japan.

(3) Japan's growth process

Japan's post-war technology imports are distinguished by the fact that they were closely tied in with investments in plants and equipment for the heavy and chemical industries. Then, brisk technology imports that were linked to the changes in these industries' structures served to adjust the conditions for independent R&D activities in the next period.

After the first half of the 1960's the so-called first laboratory establishment boom occurred in businesses, the objective of which was to improve the efficiency of preparations for an independent R&D base and the functions of R&D.

In addition to R&D in the heavy and chemical industry fields, large-scale atomic energy and space projects were started during this period.

Next, after the Oil Shocks, there was a shift in Japan's industrial structure away from mostly heavy and chemical industries to processing and assembly types of industries; it also affected the by-type-of-industry structure of disbursements for R&D costs. During the second half of the 1970's R&D costs for industries representative of the electronic field, e.g., communications, electronic and electric meters, etc., grew precipitously high.

This was a time when Japan's technology exports to primarily developing countries rose rapidly; it was when Japan began to compete with the advanced countries of the U.S. and Europe in R&D activities. In such a setting, businesses promoted internationalized and creative R&D activities and the leadership qualities of the private sector in R&D activities were remarkably demonstrated.

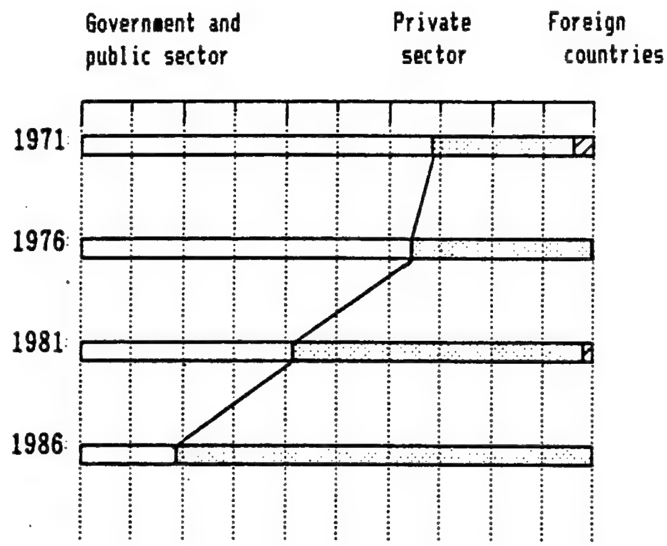
These leadership qualities of the private sector are an extremely great characteristic of the growth of Japan's R&D strength.

(4) Korea's growth process

On the other hand, Korea's S&T policies during the 1960's relied on advanced countries for technology, production facilities, and plant engineering; they pushed efficiently for product exports and import substitutions. These policies enabled rapid growth in the production and export of labor-intensive, light-industrial products. Afterwards, in order to achieve a high degree of technology growth, Korea continued to expand its plant engineering capacity and its metal-processing-machinery industry; gradually it strove to switch over from importing production equipment to importing technology; in 1966 its technology imports increased dramatically due to the normalization of its relationship with Japan.

At the onset of the 1970's Korea strove for 100% technical self-reliance in the light industry sector and at the same time worked towards the development of its heavy and chemical industries. During the 1970's the government actively promoted the education and training of research personnel and the formation of an R&D base; as shown in Figure 4, the burden of R&D costs born by the government accounted for as much as 70%. After this running start--resulting from the formation of an R&D base that was due to the evolution of government policies--private sector activities expanded in a single stroke at the start of thhe 1980's.

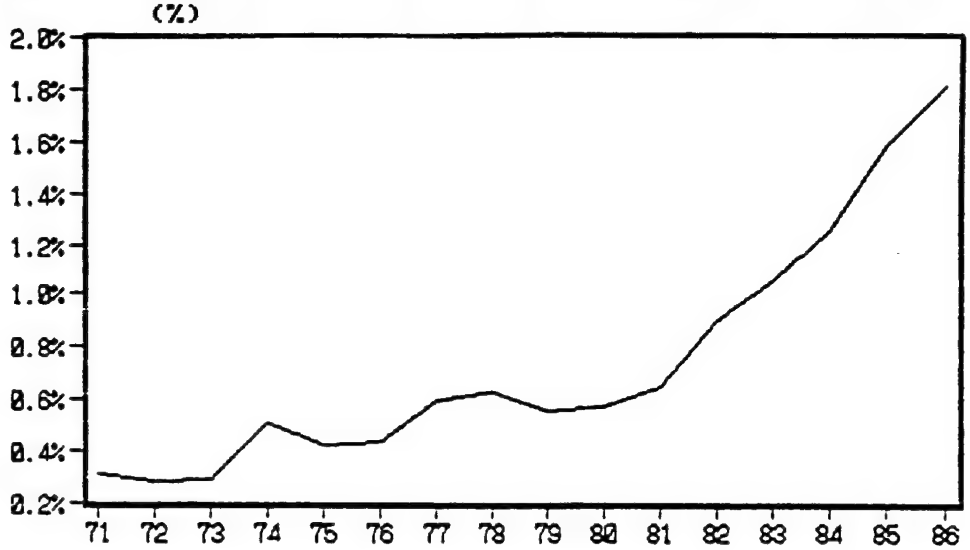
Figure 4. Distribution of R&D Expense Defrayments By Source in Korea (%)



Data: "Korea S&T Yearbook" 1987

With the 1984 liberalization of technology imports as a turning point, Korea's R&D activities also enlivened. As shown in Figure 5, the percentage of GNP that went towards research rose rapidly after the start of the 1980's.

Figure 5 Change in Korea's Ratio of Research Expenditures to GNP (%)



Data: "Korea Science and Technology Yearbook" 1987

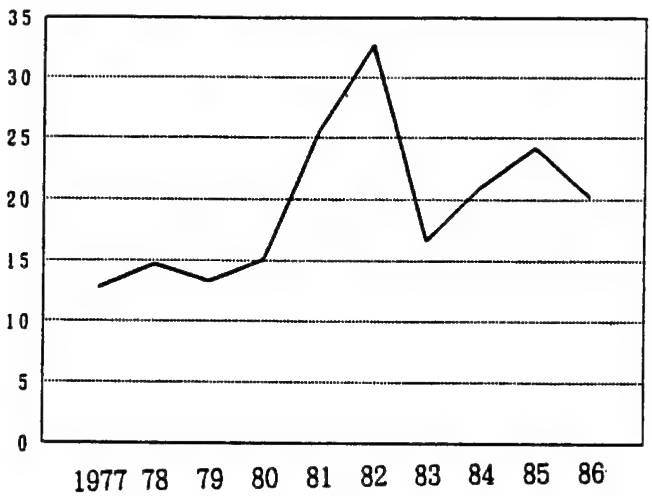
The increase in Korea's R&D expenditures, as shown in Figure 4 as well, is due in large part to private sector defrayments. During the 1970's the percentage of the costs born by the private sector was at a level of 30-35%, but in 1981 it rose to about 60% and then in 1986 to 80%.

(5) Thailand at present

In Thailand a national socio-economic development program was implemented in 5-year units starting in 1962, but the importance of S&T policies was recognized when the fourth program started in 1977. In the fifth and sixth programs after that, S&T utilization and development was for the first time held up as an official objective and the importance of S&T was definitely established.

Confronting the objectives of national development, the fifth program (1982-1986) emphasized the importance of strengthening S&T organizations, upgrading the qualities of R&D personnel, promoting R&D activities, and so forth; as shown in Figure 6, the S&T-related national budget increased. Also, the sixth program (1987-1991) continues to find solutions to social and economic problem points that could not be adequately dealt with in on-going programs up to that point, and its main objective is to move ahead with further national development.

Figure 6. Thailand's S&T-Related National Budget (100 million bahts)



Data: Thailand Science and Technology Indicators 1987

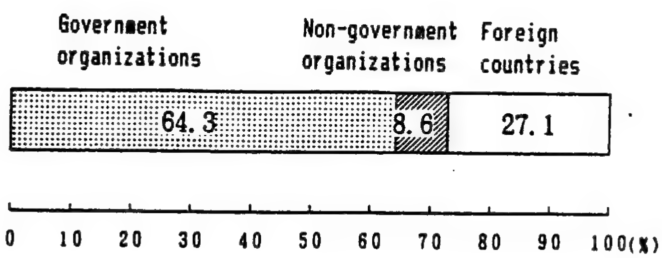
Technology imports from overseas generally hold a great deal of weight in developing countries, and Thailand is no exception. Thailand's technology imports have been rapidly expanding since 1980; in 1985 they reached a level of 2.1 billion bahts. At present the Thai government is frantically pushing forward with

policies aimed at making technology imports more positive, absorbing these imports then forming its own technology base, and increasing its R&D strength.

Nevertheless, even if the government's policy-type leadership continues to facilitate the growth of the private sector, as shown in Figures 7 and 8, a structure can be seen that resembles a dilemma in which contributions for R&D from the private sector are still only very small.

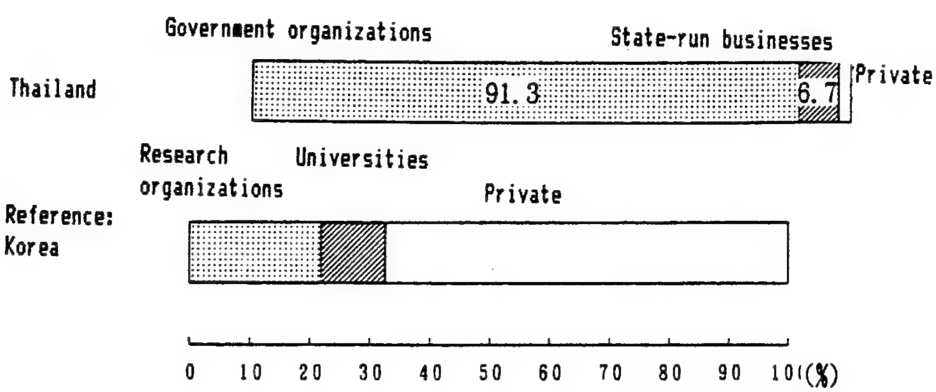
Historically, strong policy initiatives are always shown whenever a nation strives to nurture industries and build an S&T base. This was the case with both Japan and Korea. Thailand's situation certainly symbolizes this.

Figure 7. Distribution of R&D Expense Defrayments By Source in Thailand (1986)



* Total amount: 3.1450 billion bahts
Data: Thailand Science and Technology Indicators 1987

Figure 8. R&D Expenditures By Main Research Bodies (1986)



* Thailand's total amount: 3.1450 billion bahts,
Korea's total amount: 1.5232 trillion won

Data: Thailand Science and Technology Indicators 1987, Korea Science and Technology Yearbook 1987

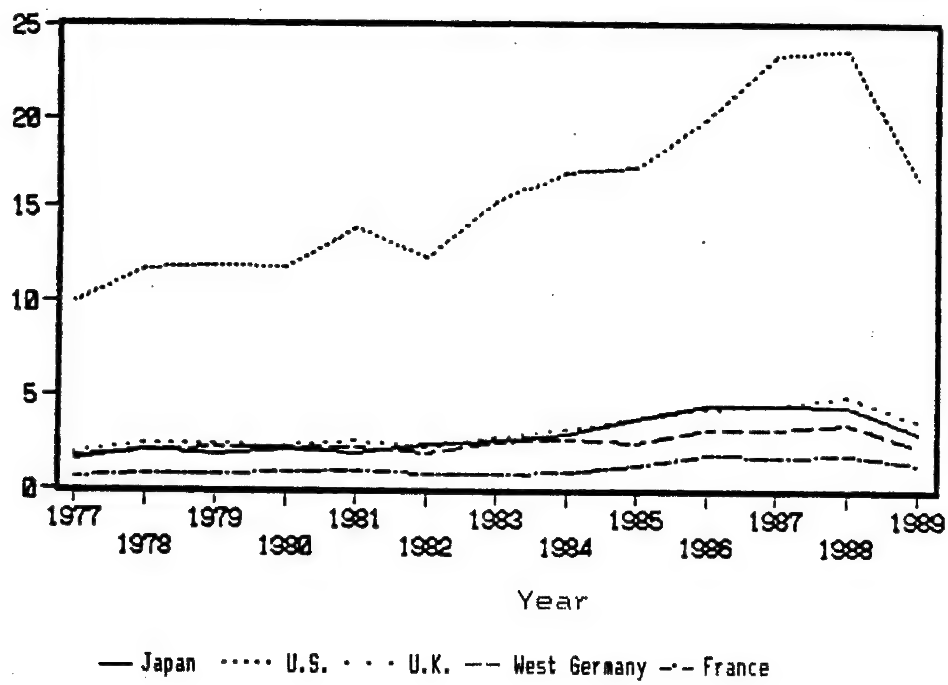
2-3 R&D Interrelationships

(1) Changes seen in computer science

Figure 9 shows the changes in the numbers of research papers generated in the field of computer science in the five advanced countries. That the U.S. is proud of the overwhelming scale in the number of its papers in comparison with other countries is evident. The shares of papers held worldwide suggests that over a ten-year period the U.S. and West German shares declined and that those of the Japanese, British and French increased, but the United States still leads in computer science R&D.

Figure 9. Changes in Number of Papers in Computer Science

Unit: 1000 papers



Note: Refer to *1 about data sources

From the trends in the number of computer science papers, it is gathered that the active R&D strongpoints are still concentrated in the U.S., and that, in connection with each country's R&D sector, the relative importance of main R&D bodies in the U.S. and in Europe is moving over to universities and public research organizations, whereas in Japan there is a visible tendency to

give businesses higher priority. From this some of the differences in R&D systems and structures can be understood.

The state of affairs in Japan can also be grasped from the trends in patents in the field of computer science. The number of Japan's patent applications in computer science has been steadily increasing since 1983 and is doubling over a five-year period; lately the percentage of patents applied for by foreigners is declining in weight from year to year.

Meanwhile, the number of U.S. patent registrations is almost doubling in the ten years between 1978 and 1986. And, Japan's share of the foreign registrants is suddenly increasing--the changes in the structure of patent registrants in the U.S. is entirely due to the strong effects of Japanese trends.

As an extremely macro characteristic suggested by the patent trends mentioned above, can we not say that Japan is continuing to intensify its R&D activities and is continuing to grow as a strongpoint for industrial technology R&D in the field of computers? In the field of computer science, the U.S. has historically been proud of its overwhelming predominance; in both basic computer science research and applied research, U.S. R&D strength is very powerful and it has been the leader of the world's development. Furthermore, the support of the U.S. government plays a great role in this development of computer science, and the acceleration of this technological development by U.S. firms is remarkable. Through the large numbers of research paper announcements and the release of patents relating to computer science, the U.S. leadership stimulates and activates the world's R&D. This leadership is also apparent in market development by U.S. firms. However, that power is relativley declining; another way of putting it is that R&D centers are continuing to scatter over to Japan. An important factor in that is the technological development strength of Japanese firms.

In Europe, too, as a result of government aid to European firms, which started with the Siemens Company of West Germany, and due to strong measures involving joint European projects, business-oriented computer science is evolving as a subject centered on the commercialization of more realistic systems. As firms' commercial development of computer science progresses, footholds for expanding basic research are emerging in Japan and Europe.

However, the U.S. has become wary about the this development in Japan and Europe lest it actually becomes a cause for competition. U.S. measures for intensified protection of intellectual property rights are emphatically pushed from this kind of background; the strong demands of the U.S. for program protection based on copyrights and for protection of corporate

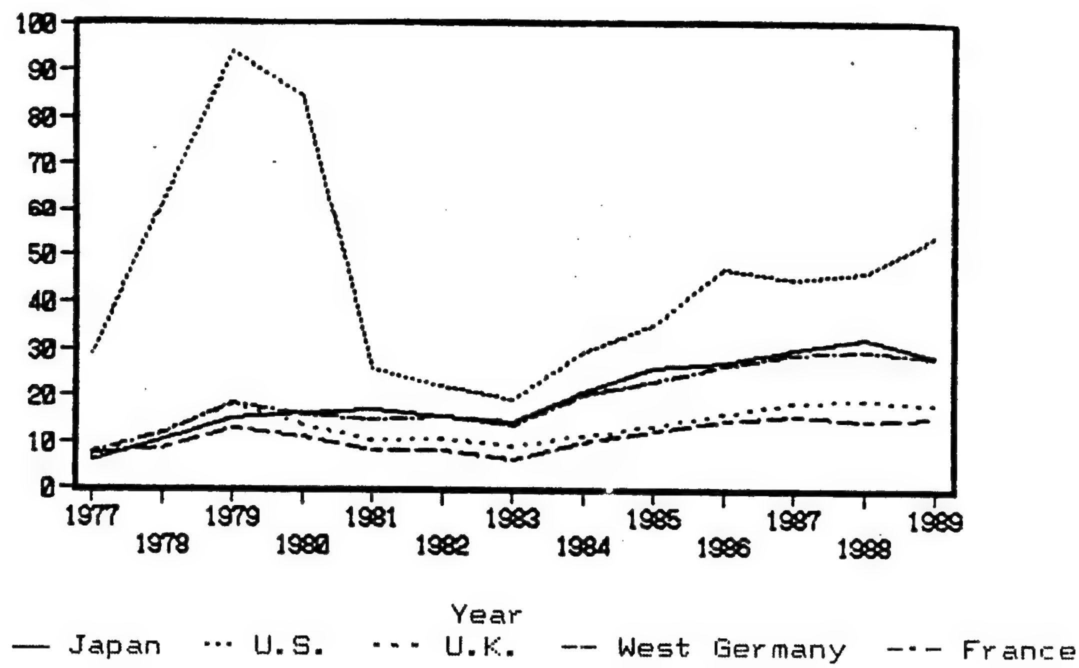
secrets--that go as far as requiring governmental compliance--have been thrust in the face of Japan and Europe. With Japan and Europe faithfully complying with the U.S. demands, we are heading towards the formation of new international cooperation.

(2) Changes seen in the life sciences

From Figure 10, which shows the transition in the numbers of papers in the field of life sciences, it is clear that the United States outrivals other countries. Especially for three years around 1979, the United States announced about five times as many papers as other countries.

Figure 10. Changes in Number of Papers in the Life Sciences

Unit: 1000 papers



Note: Refer to #1 about data sources

Although the life sciences encompass various fields such as biology, medicine, and agriculture, the rapid rise in the number of papers shown in Figure 10 points to expanding research in biotechnology-related fields, starting with genetic operations and cellular fusion.

At first the U.S. was at the center of R&D in the field of biotechnology. Then from the early 1970's there was a series of brilliant discoveries, e.g., genetic recombination was realized in 1973, and in 1978 the free use of recombinant DNA enabled insulin to be produced from *Escherichia coli.* Since the early 1980's recombinant DNA technology has been industrially utilized primarily in the fields of medicine and pharmaceuticals.

Next, Table 2 shows the changes in each country's share of the total number of papers published in 1979 and in 1989.

In this ten-year period the shares of the four other countries besides Japan declined. The total number of papers from the five countries accounted for 58.8% of the world total in 1979, but in 1989 it dropped to 32.3%, only one-third of the world's life sciences papers. This indicates that research in the life sciences is not limited to the major advanced countries but is widely distributed throughout the countries of the world.

Table 2 Change in the Shares of the Numbers of Papers

	Japan	U.S.	U.K.	W. Germany	France
1979	5.56	34.86	6.69	4.81	6.84
1989	6.41	12.05	4.10	3.48	6.30

* Same data source as Figure 9

The astounding number of announcements of U.S. papers in 1979 clearly indicates a concentration towards an S&T field that was in a period of genesis and an appearance of excellent research results being brought forth.

It can be said that the building of a foundation in the field of biotechnology, as a powerful step in S&T, was due to strength of the U.S. at this time. Later, as if the tide were pulling out, the successive dimunition of the number of U.S. papers can also be considered as a good symbolization of the U.S.

Changes in shares of the number of papers according to sector shows that most of the papers generated in each country were from universities and other organizations (mainly public research organizations).

A survey of Japanese and U.S. trends in biotechnology-related patents shows that in Japan applications related to recombinant DNA and cellular fusion have been rapidly increasing since 1979, but what stands out is the fact that an extremely large number of those applications were submitted by foreigners.

The overall trends in Japan's patent applications are characterized by a very low percentage, in comparison with other countries, of applications submitted by foreigners, but in the field of biotechnology this percentage is about the same as that of the U.S. and Europe, suggesting a state of affairs where Japan is placed in a fiercely competitive relationship.

Looking at the by-sector distribution of both Japan's and the U.S.'s own patent applicants, universities and non-profit organizations submitted most of the biotechnology patent applications during 1980 in both countries, but in 1988 the mainstream shifted to patent applications submitted by businesses.

Nevertheless, although the U.S. is the leader in biotechnology Japan's and Europe's timelags in their evolution of R&D is short. With respect to basic research and applications, as well, the current state of affairs is such that the advanced countries are making simultaneous progress.

Cooperation between the private sector and universities also plays an important role in biotechnology. Moreover, through U.S. bio-venture activities that cooperation is accelerating the activation of worldwide R&D.

(3) Changes seen in the field of superconducting materials

The emergence of high-temperature oxide superconductors was not very dramatic. From superconducting theory to applications as materials, the only impact it had was to swing existing knowledge and hypotheses away from their basis. This is clearly seen in the change in the numbers of papers on superconducting materials shown in Figure 11.

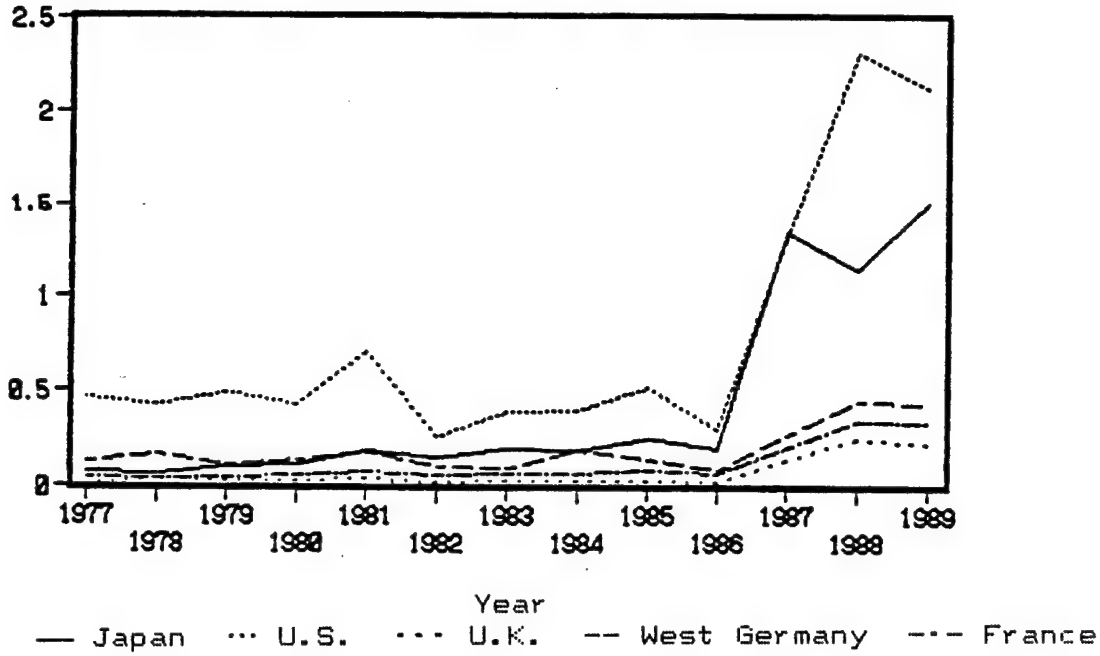
As for the sudden changes since the end of 1986, it is clearly evident that the situation with the numbers of papers about superconducting alloys up until then had been drastically changed.

Looking at the details of the early stages of superconducting materials R&D, the period between the end of 1986 and 1987 was the first period of high-temperature superconducting oxides, which consist of rare earth oxides such as lanthanum and yttrium oxides. January 1988, when Bi-Sr-Ca-Cu-oxide superconductors were announced, indicated the start of the second period. Since 1986 the numbers of announcements of papers about these superconducting oxides has increased dramatically; furthermore, it points to the evolution of concurrent global research led by Japan and the U.S. Figure 11 brings these great changes to the surface as

well as the structure of the simultaneity of Japanese and U.S. promotion of superconductor research.

Figure 11. Changes in Numbers of Papers in the Field of Superconductors

Unit: 1000 papers



Note: Refer to #1 about data sources

Changes in the shares of research papers in 1987 and in 1989 are shown in Table 3. That Japan and the United States hold the largest shares suggests that they are the world's centers for research in superconducting materials.

Table 3 Changes in Shares of Numbers of Papers on Superconductors

	Japan	U.S.	U.K.	W. Germany	France
1987	41.56	40.5	4.2	8.1	6.2
1989	32.8	46.0	4.8	9.3	7.1

* Same data source as Figure 11

Looking at the numbers of research paper announcements by sector in both Japan and the U.S., universities and national research organizations announced most of the papers in both countries, followed by industry, where R&D is rapidly evolving.

Putting together the trends in recent years results in the following:

1) Common in both universities and industry, Japan and the U.S. show a dramatic increase in the numbers of research papers. It suggests the co-existence of fierce competition and cooperation.
2) Japan shows a tendency for a more dramatic increase in the number of papers than the U.S. This suggests that Japan tackles R&D early and with a high degree of centralization.
3) For Japan the number of papers generated by industry has tended to increase since 1987, but in the U.S. the situation is declining for industry as well as universities.

   These are to point out the difference in trends in connection with the way Japan and the U.S. are dealing with research and the announcements of results from that research.

As for superconducting materials that are said to symbolize new materials, the leading roles of Japan and the U.S. are clearly seen in the area of patents; their relative positions as the world's research centers is apparent.

Changes during the early stages, when yttrium superconductors emerged, for example, show an amazingly dramatic increase in the number of patent applications. Furthermore, what should be noted is that in March 1987, i.e., a few months after superconducting oxides were announced at the end of 1986, production methods were the subject of 50% of all patent applications; if applications are also included, actually 85% of the patent applications had to do with production and application techniques. Here it is strikingly evident that Japan's industries are concentrating their energy towards the development of superconducting materials for practical use.

Japanese businesses jump in quickly, they apply for patents that are content-wise replete, and there are many businesses. As for the U.S., looking only at patent trends, the overall vitality of its industries is poor, and we can only expect it to lag behind Japan in future technological development.

In the field of superconducting materials, Japan and the U.S. lead the world in R&D, and there is no timelag between the two. It is clear that R&D is progressing concurrently. Furthermore, in

this concurrent progress, researchers' freely-chosen international cooperation is continually emerging at the academic basic-research level. It is a remarkable situation.

On the other hand, there is a difference between Japanese and U.S. industries with respect to research papers and patents. The centralized approach of Japanese industry contrasts with the low vitality of U.S. industry.

2-4 Subjects for the future

As can be seen in superconductor R&D, the advance of concurrent R&D throughout the world is being brought forth and the dispersal of international centers for R&D is being made to happen. This progress in concurrent R&D suggests the formation of a new framework of independent international cooperation among researchers and businesses.

In areas such as computer science and aerospace, too, where the foundation of knowledge and technology from the past has great significance, the formation of a new framework of international cooperation--starting with joint research projects by the developed countries of Japan, the U.S., and Europe--is becoming a necessity.

These are also thought to the developed countries' asking the world to take on a new role, a world that includes the developing countries of Asia, in paritcular, Eastern Europe, and the Communist block countries.

Nevertheless, the analysis of international structures should not be limited to the developed countries. This survey also selects and examines the Asian NIES, Korea, the ASEAN countries, Thailand, and Indonesia. However, the basic usable materials for these countries is limited.

Basic worldwide data is also too meager.

Hoping for perfection of the collection and accumulation of basic statistical data on a worldwide scale, this collection and accumulation is indispensable in Japan's future international position and role.

The following new subjects that should be investigated in the future are indicated by this research study:

1. There is a need to establish a system of indicators that would enable comparisons of R&D strength, i.e., the power to bring forth scientific knowledge and technology, in the

relationships among countries whose population, history, etc., are different.

2. As for Europe's situation in international relationships, there is a need to investigate what kinds of structuralization, in the form of historical regulatory characteristics, are possible.
3. Although we could not carry it out in this research study, we should probably investigate how Japanese researchers, technicians, and the main R&D bodies of businesses and research institutes are continuing to cope with new knowledge creation, and along what lines is that subject following.

II. Content of Research Study Results

Chapter 1. International Comparison of R&D Strength

Chapter 2. Growth Processes of R&D Strength and Tracks Left Behind by Government Policies

Chapter 3. Internationalization of R&D Activities in Business

Chapter 4. R&D Interrelationships

Chapter 5. The Subject of International Structure

II. Content of Research Study Results

Chapter 1. International Comparison of R&D Strength

International comparisons of economic or military strength, which have been attempted since long ago by the world's research organizations, governmental organizations, and universities, provide several important points of view for comprehending international relationships. But for S&T, the first attempt to compare R&D strength--as the power to bring forth new scientific knowledge and technology--was only begun during the middle of the 1960's after the second world war. These comparative analyses started to get people's attention in the 1980's when the vast politico-economic strength of the U.S. began a relative decline.

As the first step in the analysis of the structure of international R&D, this chapter attempts to make a relative comparison of R&D strength, focusing on the U.S., Europe (particularly the U.K., France, and West Germany) and Japan, countries about which it is no exaggeration to say that they lead the world in S&T and that they form the global base for S&T. This chapter also focuses on the NIES (particularly Korea), which have suddenly gained power, and on Thailand, as a major ASEAN country, and gives a general outline of the situations in those countries.

1-1 Viewpoints towards the analysis

With regard to international comparisons of R&D strength, in recent years investigations of technology balance and technological competitive strength of the free-economy sphere is being promoted in the case of OECD countries. Meanwhile, the development of indicators for assessing R&D strength is also being promoted. Although these kinds of activities are not necessarily coordinatable, they are an extremely important step in understanding the state of affairs of international competition and cooperation that is geared towards the 21st century and in investigating measures for coping with the future.

This research study, too, is an attempt at an international comparison of R&D strength based on these various situations; it examines R&D strength from the following kinds of analytical standpoints.

That is, first we defined R&D strength as follows:

> "the power to bring forth new scientific knowledge and technology"

Then, along the lines of this definition, we differentiated the following two standpoints for assessing R&D strength:

(a) Comparing the relative superiority of the levels of R&D strength
(b) Comparing the basic potential strength for R&D

As an assessment indicator, the former, (a), has the character of the R&D results group; the latter, (b) has the character of the R&D investments group.

We arranged the individual indicators that we could think of in Table 1-1-1, but there may be others; and although we indicated them in this table, there are also various discussions in the definition and substance of these indicators. However, thought of in most general terms, the table shows only those indicators for which comparative manipulation is commonly recognized.

Table 1-1-1 Viewpoints of International Comparative Analyses of R&D Strength

Standpoint of comparative assessment	Character of assessment indicator	Sub-division of assessment indicator	Items of assessment indicator
(A) Relative superiority of R&D strength standards	R&D results group	Intellectual productivity	Theses, patents
		Materialistic productivity	GNP, manufactured products and high-tech trade, technology trade, direct investments overseas
(B) Basic potential strength for R&D	R&D investments group	R&D resources	R&D funds, R&D personnel
		Research support environment	Policies, organizations and systems, society's lifestyle base, education

An important analytical viewpoint in this research study is that, even if there is debate about the pertinency of the individual indicators, comparing R&D strength is a problem involving all of the indicators of the R&D results group and of the R&D

investments group. So we attempted the analyses in conformity with the sub-divisions (a) and (b) above. As for the individual indicators, we mentioned them wherever possible in each analysis.

This research study primarily attempts to compare R&D strength in the free world. The U.S., Europe (particularly the U.K., France, and West Germany) and Japan are the main subjects. As comparisons with these developed countries, this study tries to get a grasp on the state of affairs in the NIES and ASEAN countries.

With regard to these kinds of analyses, we must clarify the following points as issues related to the basic standpoint of this research study.

(1) Present, past, and future

Analyzing the growth processes of the surveyed countries is essential in the comparison of R&D strength, but the analyses of this chapter only mention growth processes from a macro standpoint. The next chapter attempts to analyze those growth processes, i.e., the global reasons pointing to the past, present, and future steps.

(2) About the levels of R&D strength

Qualitative discussions about whether or not the creation of innovative technology occurs and about technological levels often become a problem in international comparisons. Because any assessment of such levels is a relative comparison, appropriate indicators have not necessarily been available thus far.

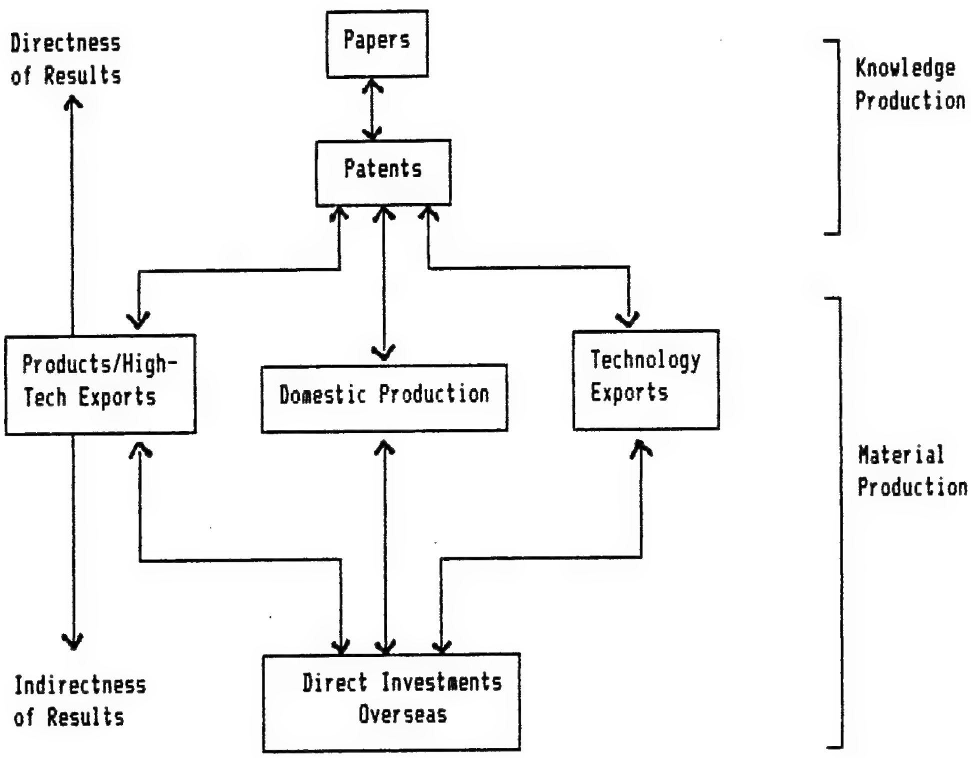
This chapter gives a grasp of the levels of R&D strength, which continue to remain as future topics, in the form of relative comparisons that are as quantitative as possible.

(3) About the interrelationship of the results group indicators

This research study uses the indicators of the R&D results group to analyze the relative superiority of levels of R&D strength. Although circumstantial economic and governmental factors must be included in the individual indicators, these indicators can be generally thought of as sub-divided into "power to produce knowledge" and "power to produce materials," as shown in Table 1-1-1. Then, their interrelationships can be shown in terms of their characteristics, as in Figure 1-1-1, while their temporal characteristics are continually taken into account.

It is probably safe to say the levels of R&D strength are examined in terms of all of these indicators.

Figure 1-1-1 Interrelationships Among Indicators of Results Group



1-2 Relative Superiority of Developed Countries' Levels of R&D Strength

1-2-1 Gross National Product

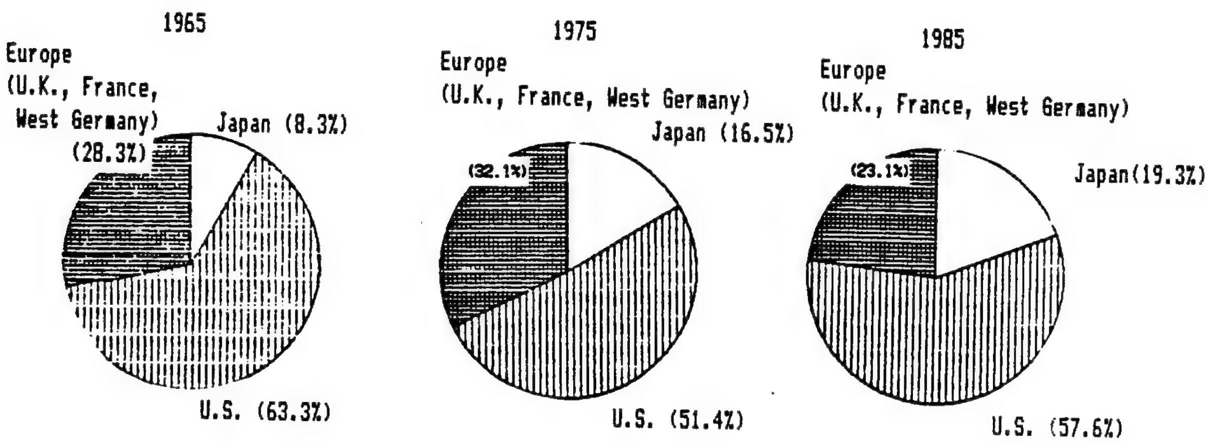
In comparing the relative superiority of the major developed countries' levels of R&D strength, we look at the changes in the major countries' GNP shares, which are thought to indicate the economic side of R&D strength throughout society while also serving as an economic base to support future R&D. Figure 1-2-1 shows the changes every ten years in the GNP shares of Japan, the U.S., and Europe.

In 1985 the U.S. GNP was about 58% of the total for Japan, the U.S., and Europe; the figure shows the remaining share split between Japan and Europe.

In the twenty years between 1965 and 1985, Japan's share suddenly expanded; the shares of the U.S. and the three countries of Europe showed a relative decline for the amount Japan's grew.

Despite the expansion of Europe's GNP share until 1975, when the U.S. economy had considerably slowed down, by 1985 Europe's share contracted significantly as a result of the U.S. recovery. Only Japan continued to grow during this time and the uniqueness of its position relative to the U.S. and Europe is distinctive. This peculiarity of Japan together with how the 1992 unification of the EC, which is confronted with dramatic changes in the Soviet Union and the Eastern European countries, will affect the distribution of GNP shares and what kind of development will that bring about in the R&D activities of Europe and the U.S. are issues that will be watched closely in the future.

Figure 1-2-1 Changes in the Shares of Gross National Product



Data: Yearly Report of National Economic Figures, Economic Planning Agency

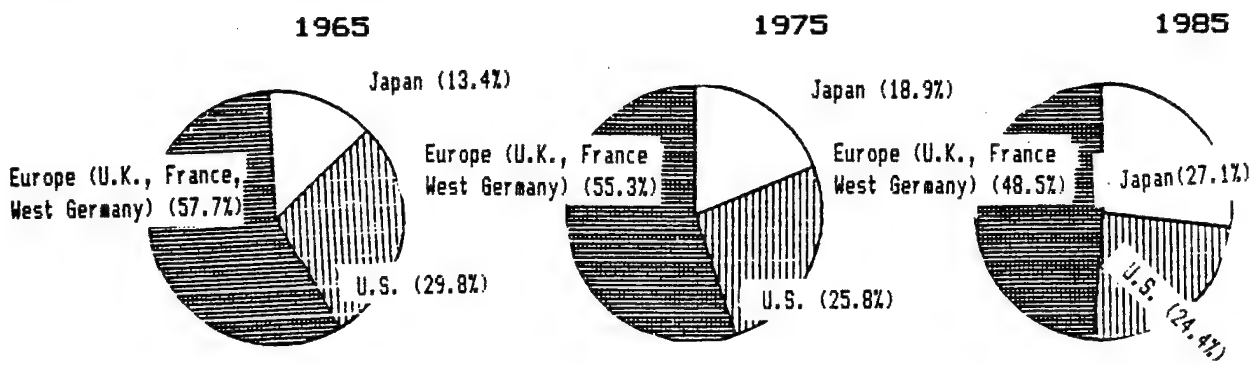
1-2-2 Manufactured Goods and High-Tech Trade

Here we will try to compare the exports of manufactured goods, as an indirect indicator of R&D strength, and the exports of high-tech manufactured goods, which are thought to indirectly indicate R&D strength in leading-edge fields. Exports of manufactured goods mean exports of all kinds of industrial products, except for goods such as foodstuffs, raw materials, and mined fuels. Exports of high-tech manufactured goods are exports of those industrial products that are separately classified as high-tech product exports according to the U.S. Department of Commerce's definitions (DOC-3) (refer to Exhibit 1), e.g., guided missiles, space rockets, communications equipment, aircraft, office equipment, pharmaceuticals, etc. (Data since 1985 is based on OECD definitions.)

Figure 1-2-2 shows the changes every ten years since 1965 in the shares of industrial product exports from Japan, the U.S., and Europe (U.K., France, and West Germany); similarly, Figure 1-2-3 shows the changes in the shares of high-tech product exports.

Looking at the changes in the shares of industrial product export volumes, the sharp decline of Europe's share, which is the sum of the exports from the U.K., France, and West Germany, and the dramatic increase in Japan's share are remarkable. As for the U.S., its share dropped about 5% over 20 years. Although that speed is insignificant in comparison with that of Europe, a close look at the relationship between Japan and the U.S. shows that a reversal in the shares is occurring--shares that differed by more than twofold in 1965 were nearly the same in 1985. With respect to exports of industrial products, Japan is overtaking the U.S. and its position is undergoing a complete turnaround from that of the 1960's. Japan has interfered in the domination of the exports market by the U.S. and Europe and it has come as far as having the greatest competitive strength; we can probably say that it has established its international superiority.

Figure 1-2-2 Changes in the Shares of Industrial Product Exports



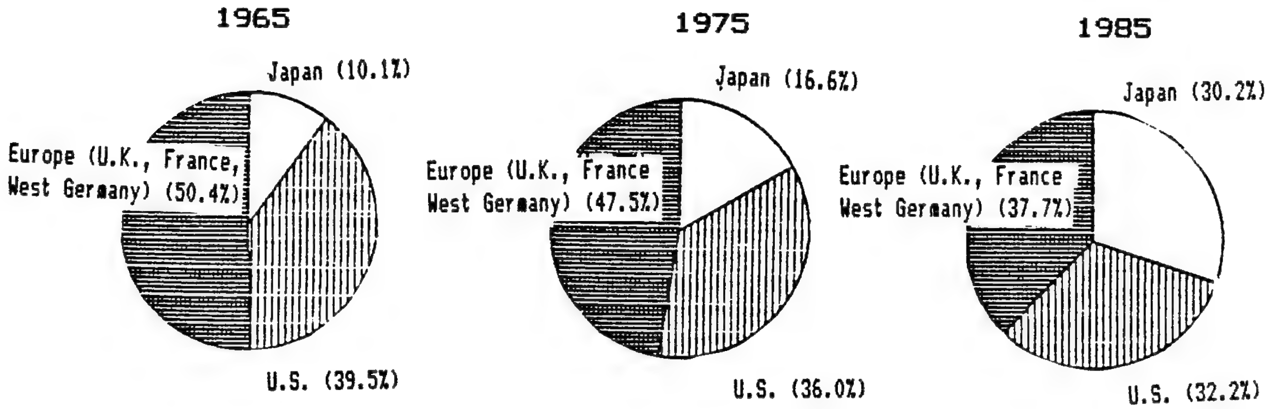
Data: U.N. Monthly Bulletin of Statistics

The ratio of Japanese, U.S., and European shares of high-tech product export volumes, which were 1 : 4 : 5 in 1965, changed to 1 : 1 : 1 in 1985; here, too, the European decline and the Japanese expansion are noticeable (Figure 1-2-3).

Looking at the change in the five countries of Japan, the U.S., and Europe with respect to the volumes of high-tech product exports points to suddenly increasing trends for each country since the latter half of the 1970's, as shown in Figure 1-2-4. Also, different transitions are evident for the two countries, Japan and the U.S., and the three countries, the U.K., France, and West Germany. At the start of the 1980's an increasing trend

continues for Japan and the U.S., in contrast to sluggish export volumes in the three European countries. Although the drop in the three European countries' share of high-tech product exports is primarily due to the declining competitive strength of England and France, West Germany's slump in the early 1980's added further momentum to that trend. The marked slump of the European powers seen in the high-tech product market is evident here. The background behind the support based on projects such as the ESPRIT project of France's President Mitterand can be seen.

Figure 1-2-3 Changes in the Shares of High-Tech Product Exports



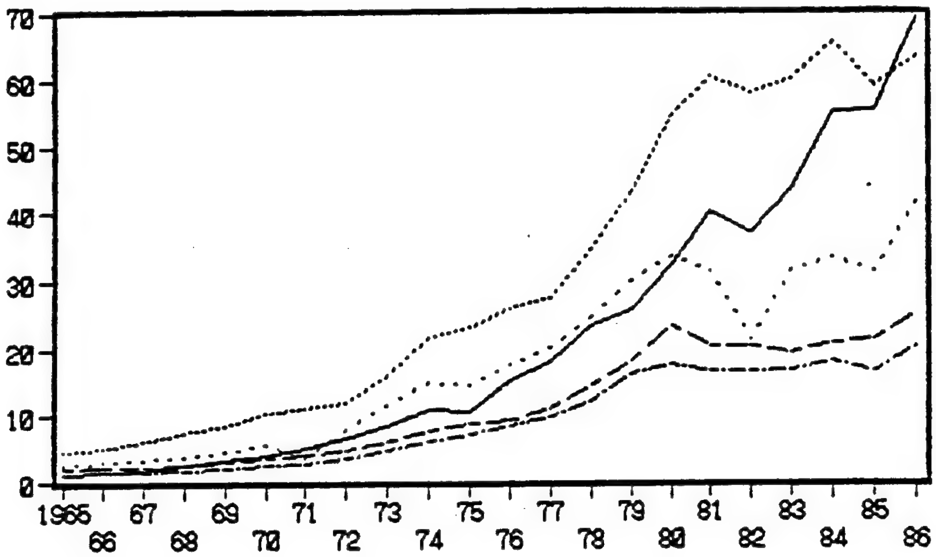
* High-tech product exports are based on the U.S. Department of Commerce's definitions (DOC-3) (1965 and 1975) and OECD definitions (1985)

Data: DOC and OECD data

This situation is also clarified by Figure 1-2-5, which shows the growth of each country's export volumes using the 1965 high-tech product export volumes as a criterion. The sluggishness of the U.S. can also be seen in Figure 1-2-5. In comparison to the U.S. and the three European countries, the growth of Japan's exports is remarkable, and the turnabout in Japan's position is extra-ordinary; this especially contrasts with the stagnation of the U.S. and the European countries after 1980. For Japan the changes in the percentage of product exports accounted for by high-tech product exports are also very striking (Figures 1-2-6 and 1-2-7). In particular, we can surmise that since the latter half of the 1970's a great change has been occuring in the U.S.'s superiority with respect to Japan-U.S. trade in high-tech products (Figure 1-2-8). We can probably say that this idiosyncrasy of Japan--a trend that is also correspondingly evident in patents and technology trade, which we will discuss later--is an indirect manifestation of the development processes of Japan's R&D and manufactured goods/production technology.

Figure 1-2-4 Changes in High-Tech Product Export Volumes

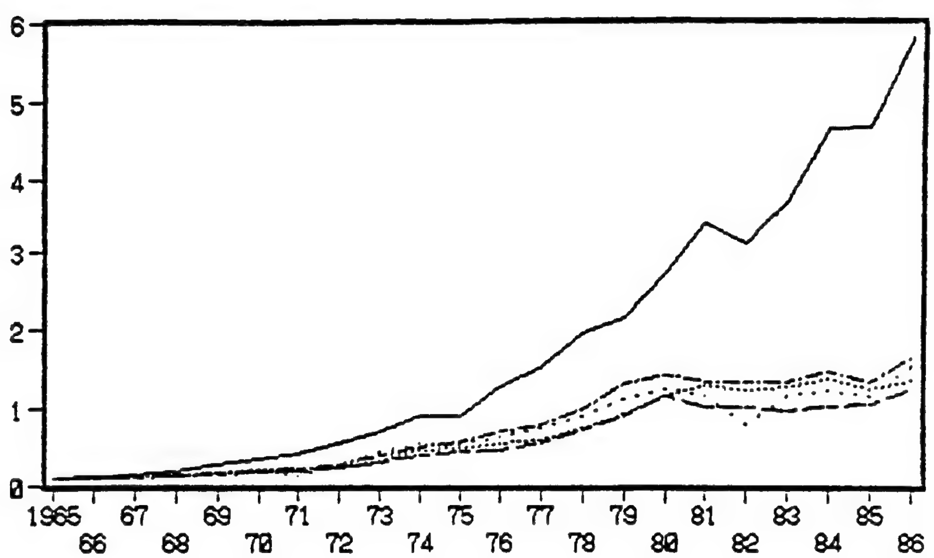
Unit: 1 Billion Dollars



* High-tech product exports are based on the U.S. Department of Commerce's (DOC-3) and OECD definitions
Data: 1965 - 1984 data is DOC data, 1985 - 1986 from the OECD data

Figure 1-2-5 Changes in High-Tech Product Export Volumes

Unit: 1000 1965 = 100



* High-tech product exports are based on the U.S. Department of Commerce's (DOC-3) and OECD definitions
Data: 1965 - 1984 data is DOC data, 1985 - 1986 from the OECD data

Figure 1-2-6 Proportion of Manufactured Goods Exports Accounted For by High-Tech Products

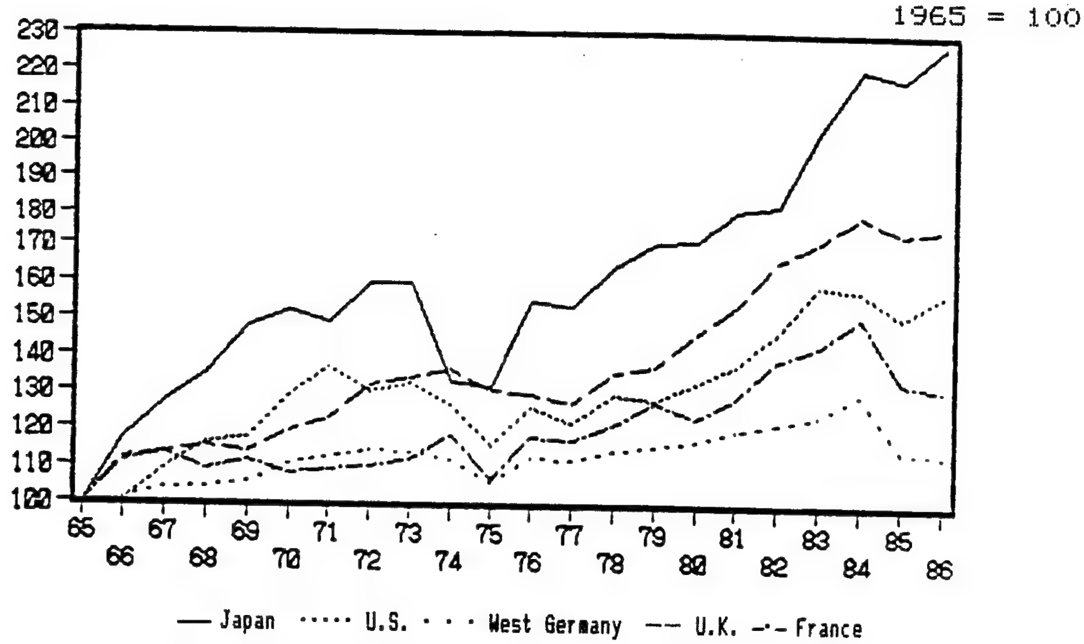
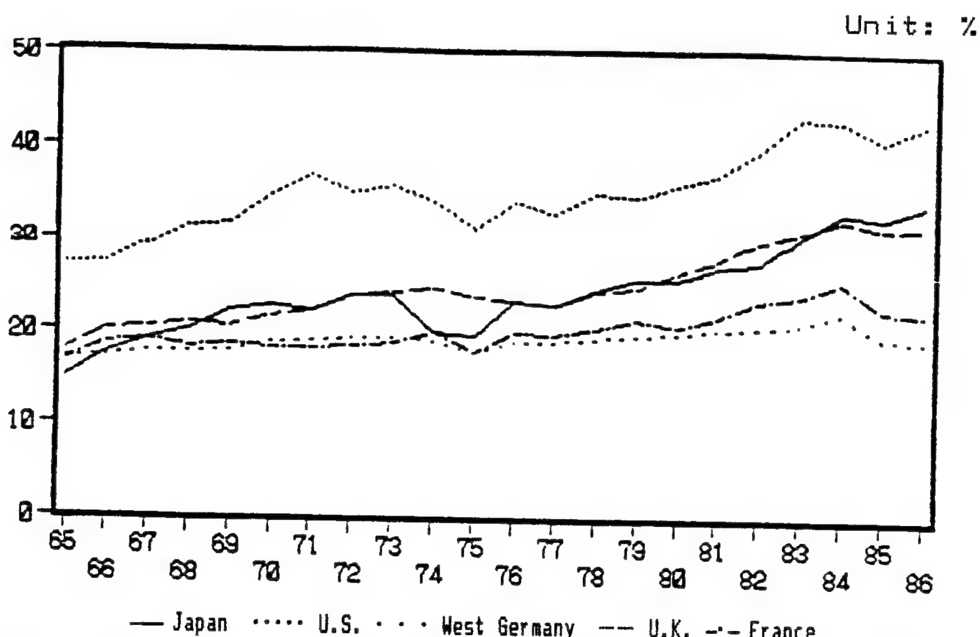
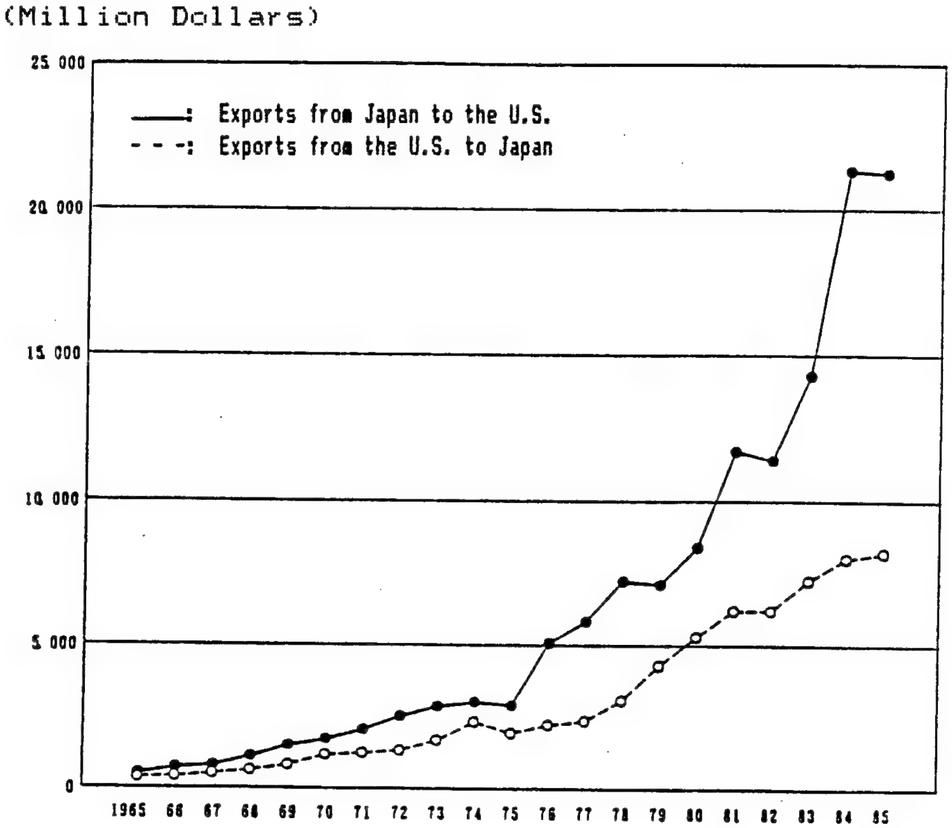


Figure 1-2-7 Percentage of Manufactured Goods Exports Accounted For by High-Tech Products



* High-tech product exports are based on the U.S. Department of Commerce's (DOC-3) and OECD definitions
Data: U.N. Monthly Bulletin of Statistics
1965 - 1984 data is DOC data, 1985 - 1986 from the OECD data

Figure 1-2-8 Japan-U.S. High-Tech Products Trade



* High-tech product exports are based on the U.S. Department of Commerce's (DOC-3) and OECD definitions

Data: The Science and Technology Resources of Japan NSF

1-2-3 Patents

Patent applications and registrations are largely divided into those in the country itself and those in foreign countries, and those filed by foreigners. When dealing with patent statistics as indicators of levels of R&D strength, the double nature of patents, that is,

(1) knowledge in the form of R&D results, and
(2) the competitive strength and superiority that go together with the exclusive possession of the technology from the results of R&D

must always be taken into account. Whether or not applications and registrations are screened is another difference.

Patent applications filed in the country itself are thought to be an indicator that expresses the power to bring forth inventions. In contrast, patent applications filed in foreign countries are the same kind of indicator as well as being something with which one can probably grab a single indicator that shows the relative superiority of R&D strength that has reached worldwide standards. Below we will try to survey the patent trends of each country from such a viewpoint.

(1) Numbers of patent applications filed in foreign countries

A look at the numbers of domestic patent applications of the five major countries in 1987 shows: 341,095 applications for Japan; 133,807 for the U.S.; 86,350 for West Germany; 74,327 forthe U.K.; and 60,412 for France. Japan had the most, amounting to about 2.5 times that of the U.S.; the figures for the three European countries are one digit smaller than those for Japan and the U.S. Furthermore, in the interval of a year Japan had 200,000 applications for utility models as well.

As for the number of applications filed by nationals in the country itself, Japan had 311,006 applications, a number that stands out as widely different than 68,671 in the U.S. and 40,696 in West Germany.

Regarding the relationship between the number of applications filed in the country itself and the number of applications filed in foreign countries, only Japan had more applications filed at home than it did abroad; all of the four other countries had more applications filed in other countries. Looking at the ratio of

applications in foreign countries to applications in the country itself:

France	3.0
West Germany	2.7
U.S.	2.4
U.K.	2.0
Japan	0.3

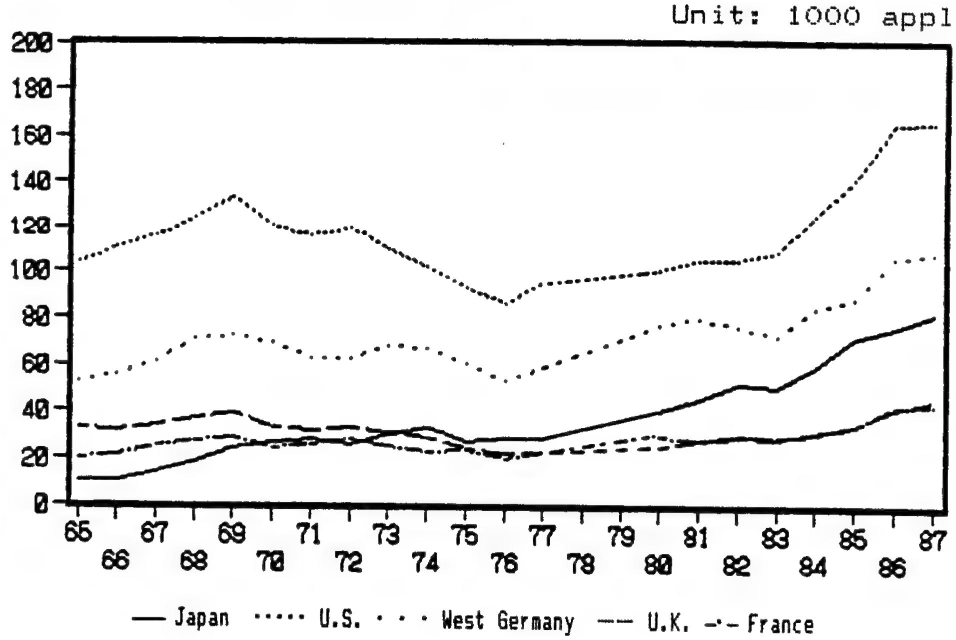
Japan has the lowest; moreover that ratio among the major developed countries is very unusual.

Making an international comparison of applications in the countries themselves is rather difficult. This is because it must take into consideration the unique structure of Japan's R&D, specifically, that which involves patents. Nevertheless, we must pay attention to this idiosyncrasy.

Patent applications in foreign countries can be thought of as indicating the degree to which R&D strength has attained worldwide levels and the competitive strength thereof. Figure 1-2-9 shows the yearly changes in the numbers of applications filed in foreign countries; Figure 1-2-10, the growth in those numbers based on figures from 1965 . What is unique about these figures

Figure 1-2-9 Changes in the Numbers of Patent Applications Filed in Foreign Countries

Unit: 1000 applications

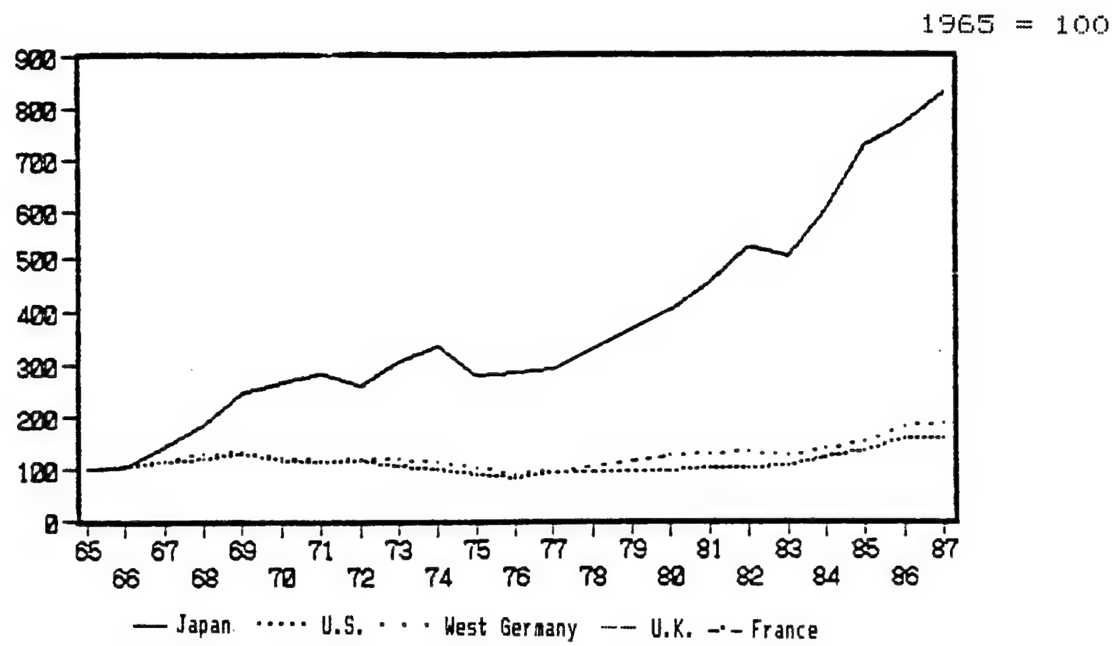


* Includes numbers due to EPC applications
Data: Yearly Report of the Patent Office, EPO Journal May 1986

is that a designated country for applications based on the EPC (European Patent Convention) is computed as one country. These kinds of statistics have never been seen until now. PCT (Patent Cooperation Treaty) applications were not included here because the scale of the total number of applications is very small.

As for the number of applications filed in foreign countries for Japan's patents during the past 20 years, it was greater than that of the U.K. and France in the first half of the 1970's and thereafter has been closing in on second-place West Germany. In 1987 Japan filed about half as many applications in foreign countries as did the U.S. and about three-fourths as many as West Germany did. Although the growth rates for the four other countries besides Japan varied somewhat, it is safe to say that there was no great fluctuation. However, only Japan shows a remarkable increase in the number of applications--over a period of 20 years the number of its patent applications in foreign countries rose by a factor of eight. It is a very dramatic change.

Figure 1-2-10 Changes in the Numbers of Patent Applications Filed in Foreign Countries



* Includes numbers due to EPC applications
Data: Yearly Report of the Patent Office, EPO Journal May 1986

Japan's R&D strength, which can be seen in the number of patent applications filed in foreign countries, is rapidly expanding; we can probably say that it is now next to that of the U.S. and West Germany.

Nevertheless, this great change of Japan's, as seen in Figure 1-2-10, certainly suggests

1) the power of Japan's R&D strength to develop at global levels and the increase of that power, and
2) Japan's increasingly stronger competitive power in the future

as well. The relative changes in the number of applications filed in foreign countries for the U.S. and Europe are very similar, and the gradual increase of those numbers is probably attracting attention, too. U.S. and European rivalry in economic power and in R&D strength is also thought to be suggested here.

(2) Patents applications and registrations by foreigners

Figures 1-2-11 and 1-2-12 show the changes in patent foreigner ratios in Japan and the U.S., respectively. Here "foreigner ratio" expresses the percentage that applications (registrations) by foreigners account for in the total number of applications (registrations), which is a sum of the number of applications (registrations) by nationals in their own country and the number of applications (registrations) by foreigners.

According to these figures, Japan is in a trend where the foreigner ratios of both patent applications and registrations are declining. On the other hand, in the U.S. the tendency for that ratio to increase is clearly evident.

When looking at the relationships among Japan, the U.S., and Europe in terms of the relative superiority of R&D strength, changes in the ratio of foreigners that hold patent rights, as an indicator of the country's domestic superiority, glaringly point out the changes in the country's relative superiority.

The foreigner ratio in the U.S. increased from about 20% to about 50% during the 1960's; lately it reached the point where patents filed by Japanese account for the largest share. The increase in the share of applications that are from Japan is astounding. As shown in Figure 1-2-13, in the changes over the past 20 years, Japan accounts for as much as 40% of the total number of applications from foreign countries and 20% of all U.S. patent applications. A relationship of intense competition between the U.S. and Japan is suggested.

Figure 1-2-11 Foreigner Ratios in Japan's Patents

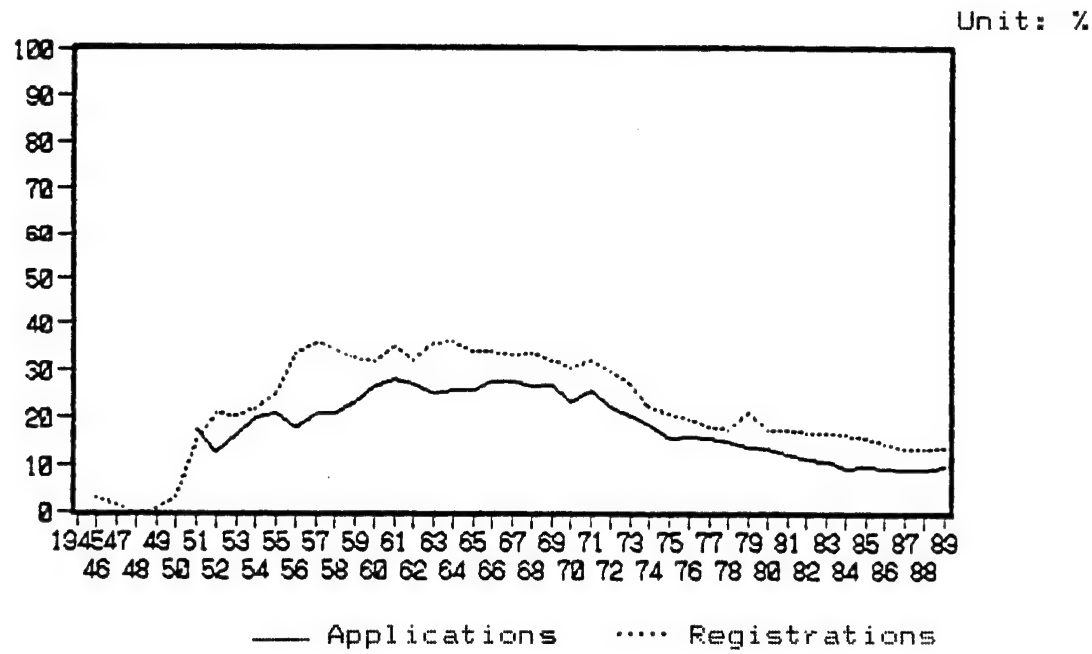
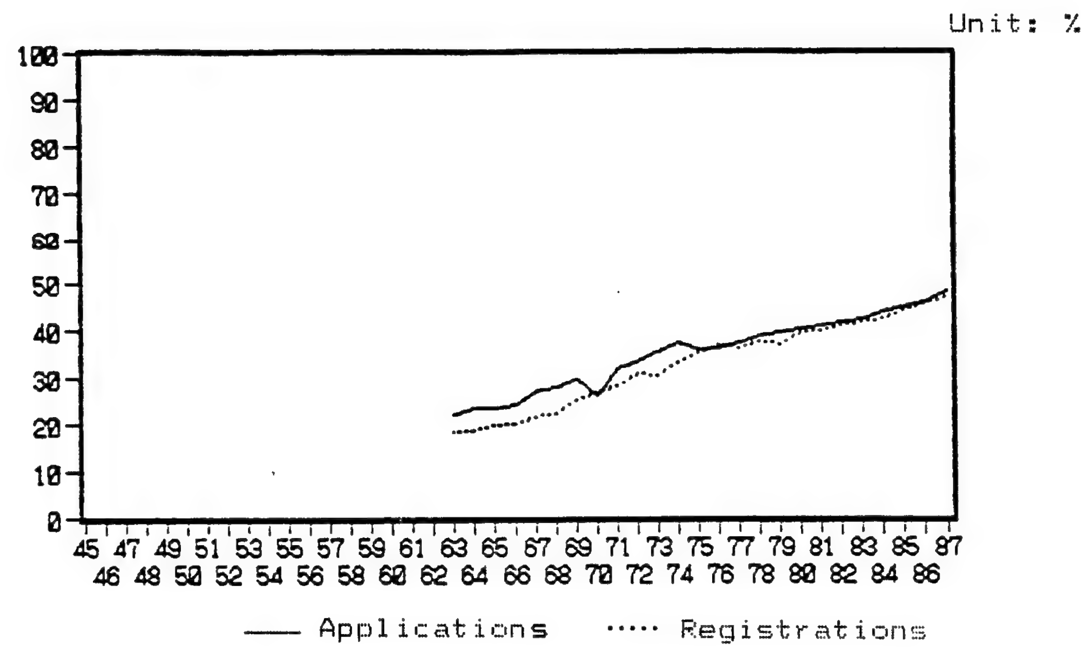


Figure 1-2-12 Foreigner Ratios in U.S. Patents



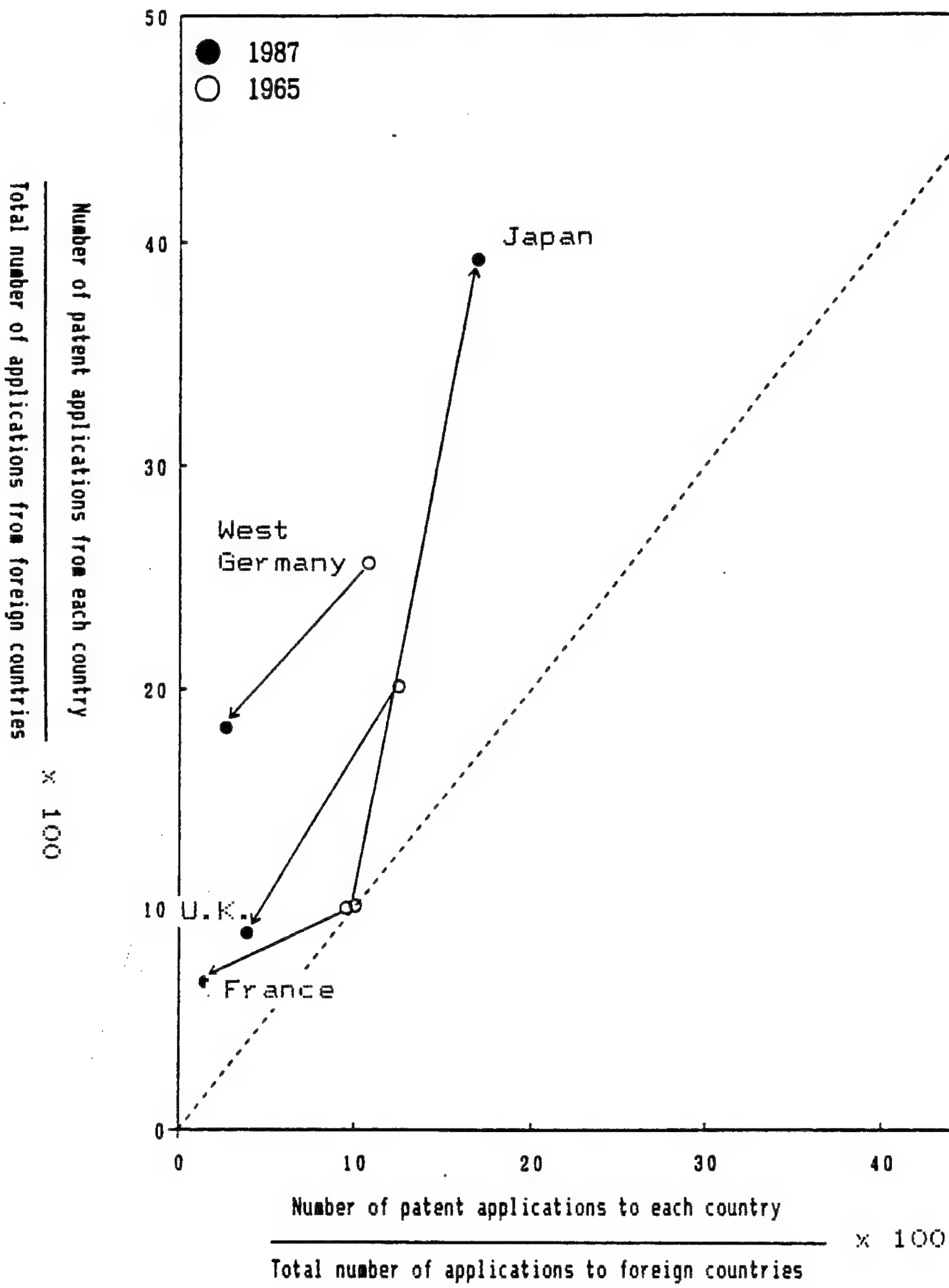
* Foreigner Ratio = (Number of applications (registrations) by foreigners/
Total number of applications (registrations)) x 100

Data: Yearly Report of the Patent Office, WIPO

The situation in Europe, as can be seen in the U.K., for example, is such that since the 1960's the foreigner ratio already reached more than 70%, of which the largest share is held by the U.S. In France, the foreigner ratio is a little less than 80% (Figure 1-2-14); in West Germany it reached 60% (Figure 1-2-15). The relative decline of the countries' R&D strength and an intensely competitive relationship can probably be read from this.

In contrast, the foreigner ratio in Japan--where more than 30% of the patent rights were held by foreigners during the 1960's--fell abruptly in the 1970's and is receeding to a level of about 10%. Furthermore, Japan's patent applications in foreign countries in 1986 was eight times greater than in 1965, and Japan holds the next largest share after the U.S. and West Germany. This increase is astounding in comparison with Europe--the improvement of Japan's R&D strength is strikingly evident. Japan's current situation is also unique among the three poles of Japan, the U.S., and Europe.

Figure 1-2-13 State of U.S. Patent Applications By Nationality



* Includes numbers due to EPC applications
Data: WIPO

Figure 1-2-14 Foreigner Ratios in France's Patents

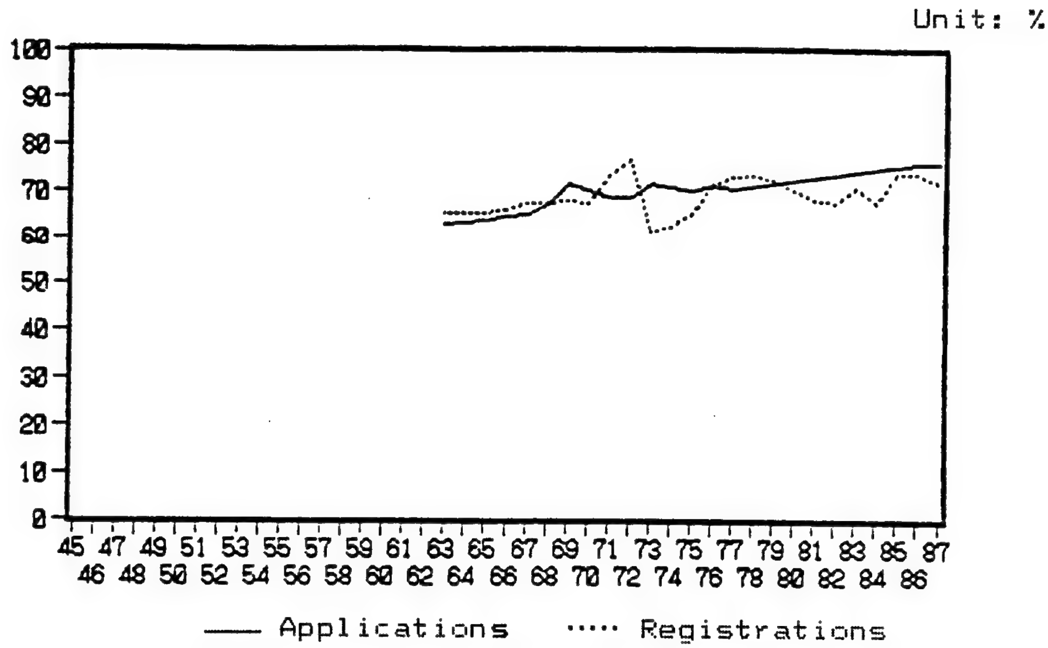
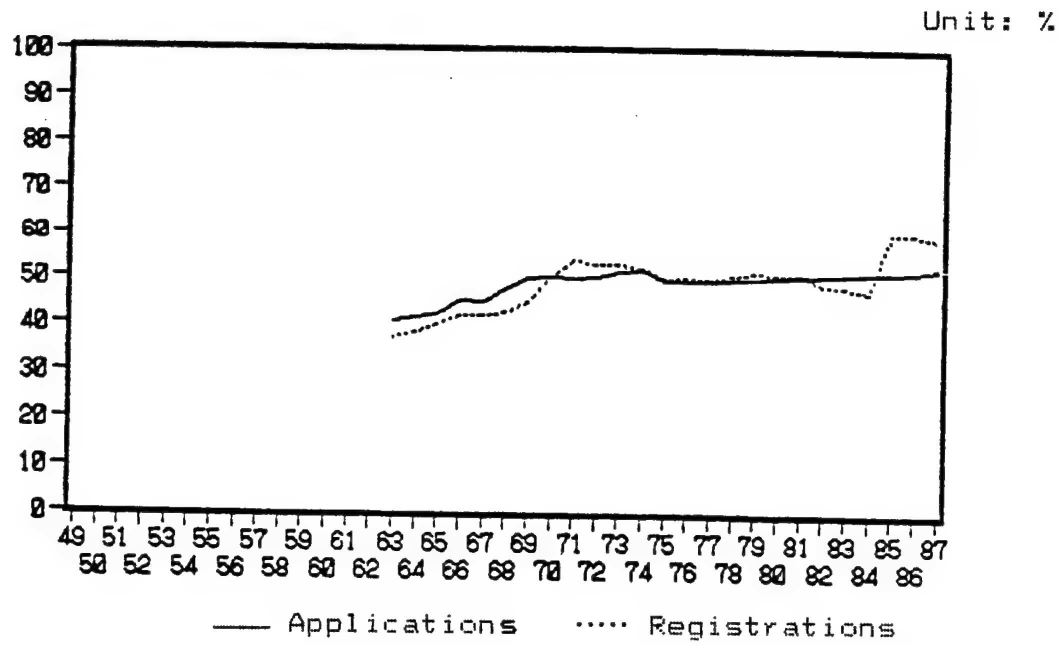


Figure 1-2-15 Foreigner Ratios in West Germany's Patents



* Foreigner Ratio = (Number of applications (registrations) by foreigners/
Total number of applications (registrations)) x 100

* Numbers of applications include EPC applications

Data: WIPO

1-2-4 Technology Trade

Looking at the volume of technology trade of the five major developed countries in 1988, U.S. technology exports were overwhelmingly large (1.3762 trillion yen), greatly outpacing those of Japan (209.7 billion yen) and West Germany (128.5 billion yen).

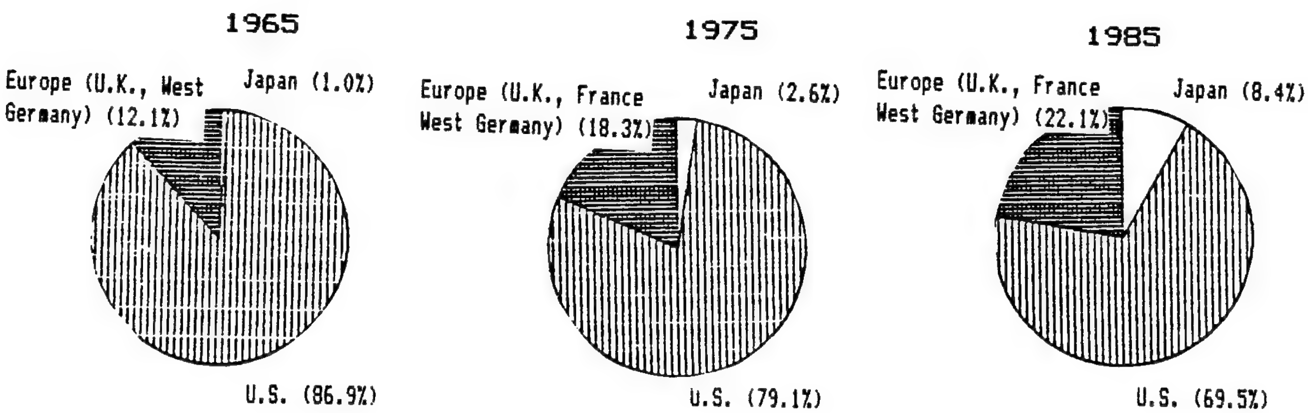
As for volumes of technology imports, Japan's were the highest (642.6 billion yen) of the five countries, followed by West Germany (279.5 billion yen) and the U.S. (262.6 billion yen).

Looking at this in terms of the ratio of income to outlays in the technology trade of 1987, the U.S. earned 6.64 times more than it spent; the U.K., 0.92; France, 0.56; West Germany, 0.49; and Japan, 0.32.

(1) Shares of Technology Exports

Figure 1-2-16 compares the changes every ten years of the U.S., Japanese, and European (British, French, and West German) shares of technology exports.

Figure 1-2-3 Changes in the Shares of High-Tech Product Exports



* Data for 1965 does not include France

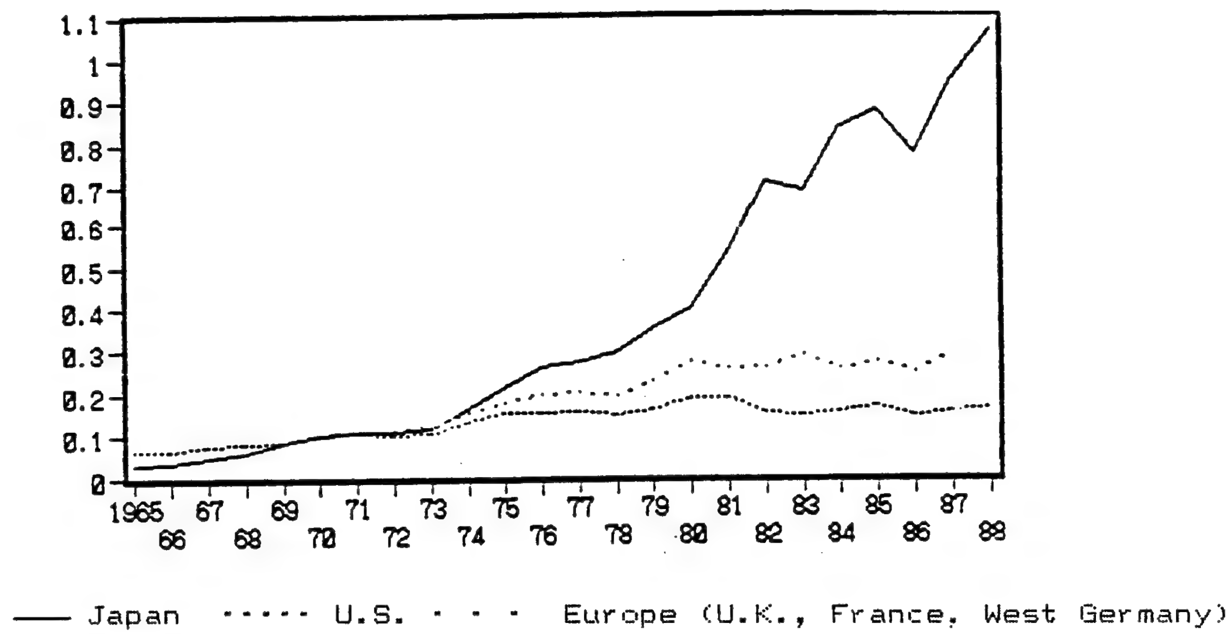
Data:
- Japan "Monthly Report on International Balance of Payments Statistics" Bank of Japan
- U.S. "Survey of Current Business"
- W. Germany "Monthly Report of the Deutsche Bundesbank" Deutsche Bundesbank
- U.K. "Business Monitor Overseas Transaction" (1965,1970 data) Department of Trade and Industry
  "British Business" (1985 data)
- France "Statistique and Etudes Financieres"
  "La Balance des Paiements de la France"
  Ministere de l'Econmi, des Finance et du Budget

As for the volumes of technology exports, over the past twenty years the increase of Japan's and Europe's shares, and the decrease of the shares of the U.S. are noticeably apparent. For the U.S. and Europe, the changes in the shares of technology export volumes indicates a totally reversed situation than the changes in shares of industrial product and high-tech product export volumes. Japan's shares of the volumes of all of those kinds of exports expanded.

In Figure 1-2-17, which shows the changes in volumes of technology exports using 1970 as a basis for comparison, the steep growth of Japan's technology export volumes becomes all the more conspicuous when compared with those of the U.S. and Europe.

Figure 1-2-17 Changes in Volumes of Technology Exports

Unit: 1000 1970 = 100



Data:
- Japan "Monthly Report on International Balance of Payments Statistics" Bank of Japan
- U.S. "Survey of Current Business" DOC
- W. Germany "Monthly Report of the Deutsche Bundesbank" Deutsche Bundesbank
- U.K. "Business Monitor Overseas Transaction" (1965 and 1970 data) Department of Trade and Industry; "British Business" (1985 data)
- France "Statistique and Etudes Financieres" "La Balance des Paiements de la France" Ministere de l'Econmie, des Finance et du Budget

In technology exports, which can be thought of as indicating the stock effectiveness of past R&D,

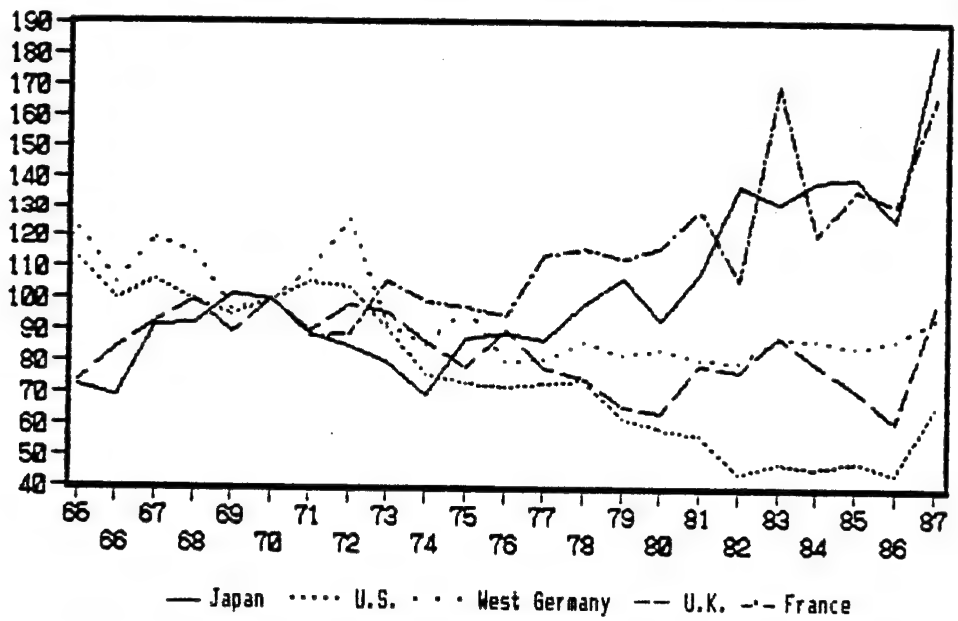
1) the level of technology, and
2) the competitive strength of technology

are directly expressed. Indeed these influence the global strategies of exporting countries, e.g., strategies such as multi-nationalization, and local production/sales to replace product exports.

Japan's changes can be seen in the change of the scale of its technology export volumes and also in the increase of the ratio of technology export volumes to industrial product export volumes. In contrast to the almost 30% decline in that ratio for the U.S. in comparison with 1970, Japan's increased to more than 80%.

Figure 1-2-18 Ratio of Technology Export Volumes To Industrial Product Export Volumes

1970 = 100



* Ratio = Technology Export Volumes / Industrial Product Export Volumes × 100

Data: Technology Export Volumes

- Japan "Monthly Report on International Balance of Payments Statistics" Bank of Japan
- U.S. "Survey of Current Business" DOC
- W. Germany "Monthly Report of the Deutsche Bundesbank" Deutsche Bundesbank
- U.K. "Business Monitor Overseas Transaction" Department of Trade and Industry "British Business"
- France "Statistique and Etudes Financieres" "La Balance des Paiements de la France" Ministere de l'Econmie, des Finance et du Budget

Industrial Produst Export Volumes: U.N. Monthly Bulletin of Statistics

(2) Degree of Dependence on the Introduction of Technology

Because an up-to-date assessment of R&D strength cannot necessarily be accomplished by looking at only the compensation for furnishing and introducing technology, international comparisons based on the degree of dependence on technology introduction are also being studied. This degree of dependence on technology introduction is an indicator that is expressed as

$$\text{Degree of dependence on the introduction of technology} = \frac{\text{Amount paid to compensate for technology introduction}}{\text{Corporate R\&D costs} + \text{Amount paid to compensate for technology introduction}}$$

and it is thought to suggest the degree of reliance on technology that is introduced in situations where a firm is convinced that the time is right for establishing a certain technology, or where a firm hopes to bring forth the seeds for a certain technology.

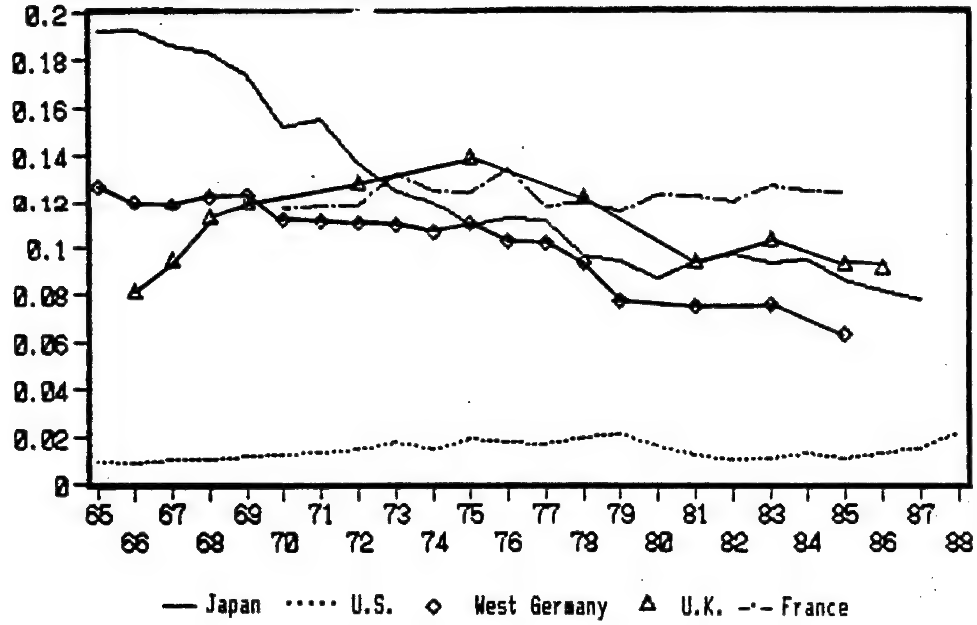
This is an essential indicator for measuring the importance of the introduced technology with respect to a country's R&D, and the relative importance of independent R&D in the introduction of technology. The OECD also processes its data using the same kind of idea.

Figure 1-2-19 shows how the degree of reliance on technology introduction changes for firms in the five developed countries.

In 1985 the country least dependent on the introduction of technology was the U.S., 0.011; next was West Germany, 0.064; then Japan, 0.87; the U.K., 0.094, and France, 0.124. The U.S. degree of dependence on technology introduction is overwhelmingly low.

Yearly changes in the degree of dependence on technology introduction are clear from Figure 1-2-19, in which the tendency in Japan and West Germany for that dependence to decrease can be seen. Japan's case is especially salient. As for the U.K., there are large fluctuations; France and the U.S. maintain a nearly constant value. If the lessening of the degree of reliance on technology introduction means that independent R&D strength is building up, then the improvements in Japan's and West Germany's R&D strength are remarkable.

Figure 1-2-19 Changes in Degree of Dependence on Technology Introduction



* Degree of dependence on the introduction of technology = Amount paid to compensate for technology introduction / (Corporate R&D costs + Amount paid to compensate for technology introduction)

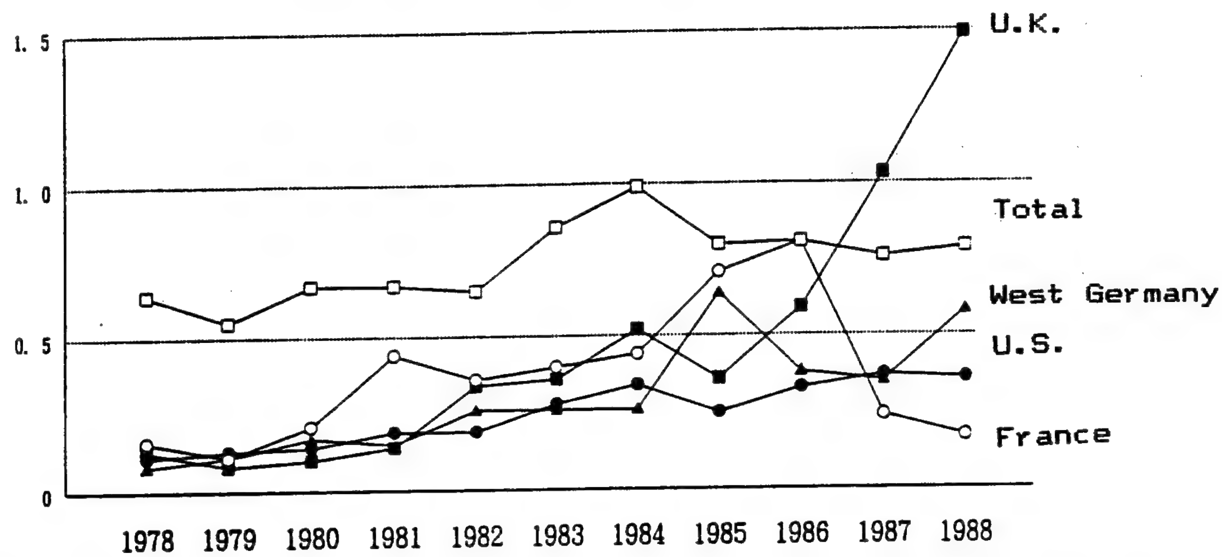
Data:

Japan	"Monthly Report on International Balance of Payments Statistics" Bank of Japan, "Investigative Report of Scientific and Technological Research" Management and Coordination Agency	
U.S.	"Survey of Current Business" DOC, NSF statistics	
W. Germany	"Monthly Report of the Deutsche Bundesbank" Deutsche Bundesbank, OECD statistics	
U.K.	"Business Monitor Overseas Transaction" (1965 and 1970 data) Department of Trade and Industry "British Business" (1985 data), OECD statistics	
France	"Statistique and Etudes Financieres" "La Balance des Paiements de la France" Ministere de l'Econmie, des Finance et du Budget, OECD statistics	

(3) Technology Trade By Partner-Country

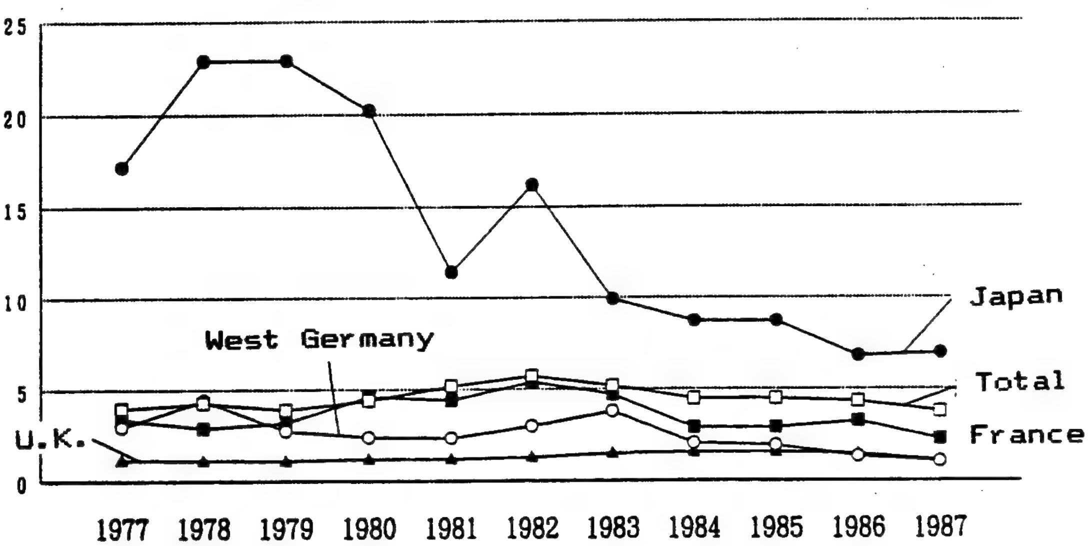
Here we will attempt to compare the ratio of exports to imports for Japan and the U.S. in their trade with other developed countries. Figures 1-2-20 and 1-2-21 show the changes in the ratio of technology exports to imports by trading partner. Incidentally, the data on Japan's technology trade is not from the Bank of Japan, but uses data from the Management and Coordination Agency's "Investigative Report of Scientific and Technological Research."

Figure 1-2-20 Ratio of Exports to Imports in Japan's Technology Trade, By Partner-Country



Data: "Investigative Report of Scientific and Technological Research" Management and Coordination Agency

Figure 1-2-21 Ratio of Exports to Imports in U.S. Technology Trade, By Partner-Country

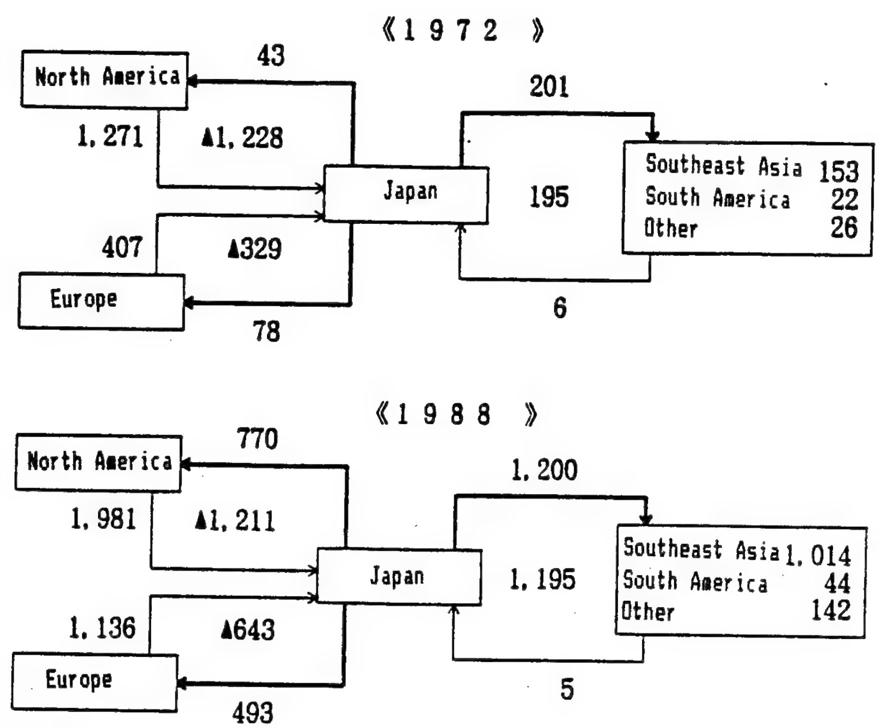


* Affiliate-company transactions not included
Data: DOC

For Japan in 1988, the ratio of exports to imports in technology trade with the U.K. was the highest, 1.49; with West Germany, it amounted to 0.58; with the U.S., 0.36; with France, 0.24. The ratio in trade with the U.K. was greatly improved, and there have been relative improvements in the ratios for trade with all of the other countries except France.

For the U.S. in 1987, the ratio of exports to imports in technology trade with Japan was the highest, amounting to 6.9; with France, 2.3; with the U.K., 1.1; and with West Germany, 1.0. The ratio is high for technology trade with Japan. The ratio for trade with Japan is higher than 3.8, the ratio for all U.S. technology trade; in contrast, the ratios for trade with the other three countries is lower than the overall ratio. Over the years the ratio for technology trade with Japan is gradually approaching the level of the other three countries. This can be interpreted as a continual decrease in the degree to which Japan relies on the U.S. (also refer to Figure 1-2-22).

Figure 1-2-22 Structure of Technology Transfer as seen with Japan at the Center



Unit: 100 Million Yen
Data: "Investigative Report of Scientific and Technological Research" Management and Coordination Agency

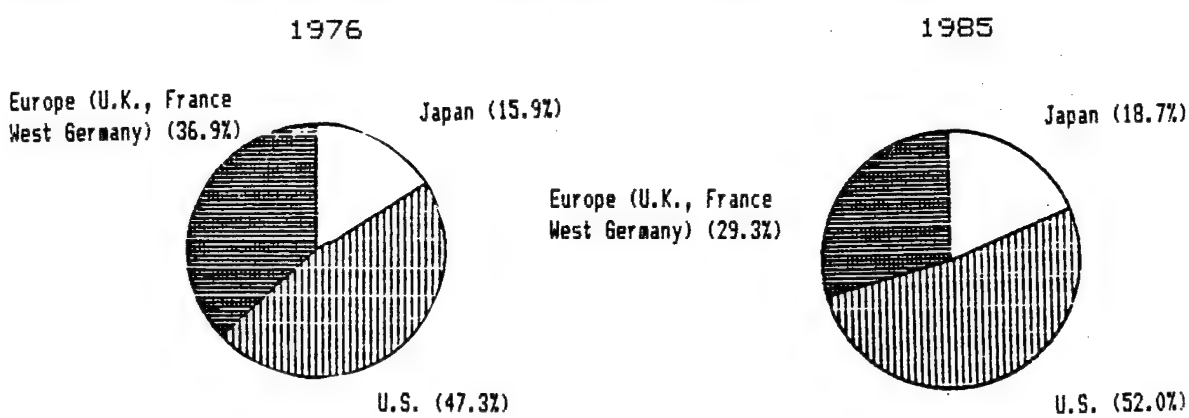
1-2-5 Papers

Research papers and patents are thought to indicate the relative superiority of the level of R&D strength, as mentioned in the analysis viewpoint of 1-1, but we can also deal with them from the standpoint of the intellectual productivity of research personnel.

As for statistics on papers, little that can be suitably used has been found, but because the Ministry of Education's "International Comparative Study of the Numbers of Academic Research Papers" was recently released, we can use these statistics. Research papers from 24 leading-edge fields related to the physical sciences, engineering, and medicine are the subjects of the Ministry of Education's study.

Figure 1-2-23 shows the shares by nationality of authors from Japan, the U.S., and Europe (the U.K., France, and West Germany) whose papers can be considered to be at the level of worldwide standards. After comparing the shares in 1985 with the shares of research personnel, shown later in Figure 1-3-6, an unbalance is apparent in Japan and Europe. The U.S. is almost balanced.

Figure 1-2-23 Changes in Shares of Numbers of Papers



Data: "International Comparative Study of the Numbers of Academic Research Papers" Ministry of Education

On the other hand, however, Europe's retrogression is evident. Comparing its share of the papers in 1976 with that of 10 years before, it receeded from 36.6% to 29.3%; conversely the U.S. shows a significant increase. Perhaps we can say that it is the retrogressive phenomenon of Europe. If the R&D strength of universities and other such academies is revealed in research papers, then we can probably say that the vitality of European academies, which boast of a long tradition, is waning; that the

strength of the U.S. is increasing; and that Japan is following behind the U.S.

Also, looking at the relative percentages of Japan and the U.S., as shown in Table 1-2-1, Japan's weight increased during the ten years from 1973 to 1982, and although the U.S. is proud of its overwhelming superiority, it is apparent that its percentage is decreasing. Europe's retrogression and the heightening of Japan's intellectual superiority due to the generation of research papers is suggested.

Table 1-2-1 Comparison of Japanese and U.S. Shares in Numbers of S&T Papers

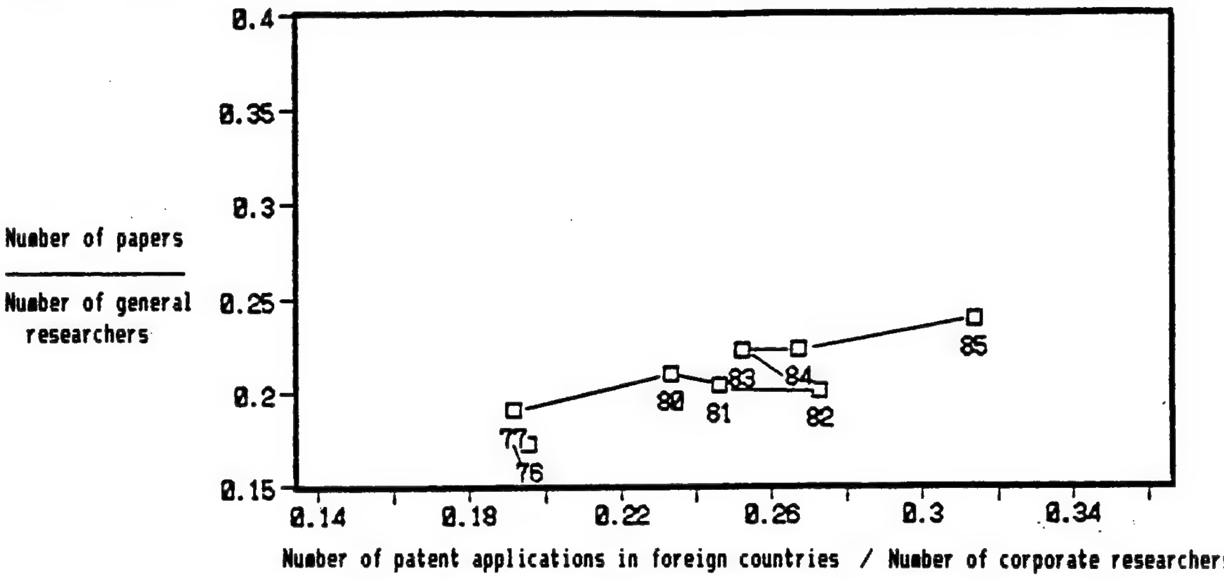
Field	Japan		U.S.	
	1973	1982	1973	1982
BIOLOGY	5.3	6.6	46.4	44.0
BIOMEDICINE	4.0	6.5	39.2	41.1
CHEMISTRY	9.4	11.6	23.3	21.9
CLINICAL MEDICINE	3.5	5.6	42.8	42.1
EARTH & SPACE	2.0	2.1	46.7	43.1
ENGINEERING	5.4	7.9	41.8	41.5
MATHEMATICS	3.9	6.0	47.9	38.7
PHYSICS	6.5	9.0	32.7	29.6
ALL FIELD	5.1	7.3	39.2	37.2

Data: The Science and Technology Resources of Japan, NSF, 1988

Figures 1-2-24 and 1-2-25 are year-to-year comparisons in terms of per-researcher productivity of Japan and the U.S. with respect to the numbers of patent applications in foreign countries and research papers.

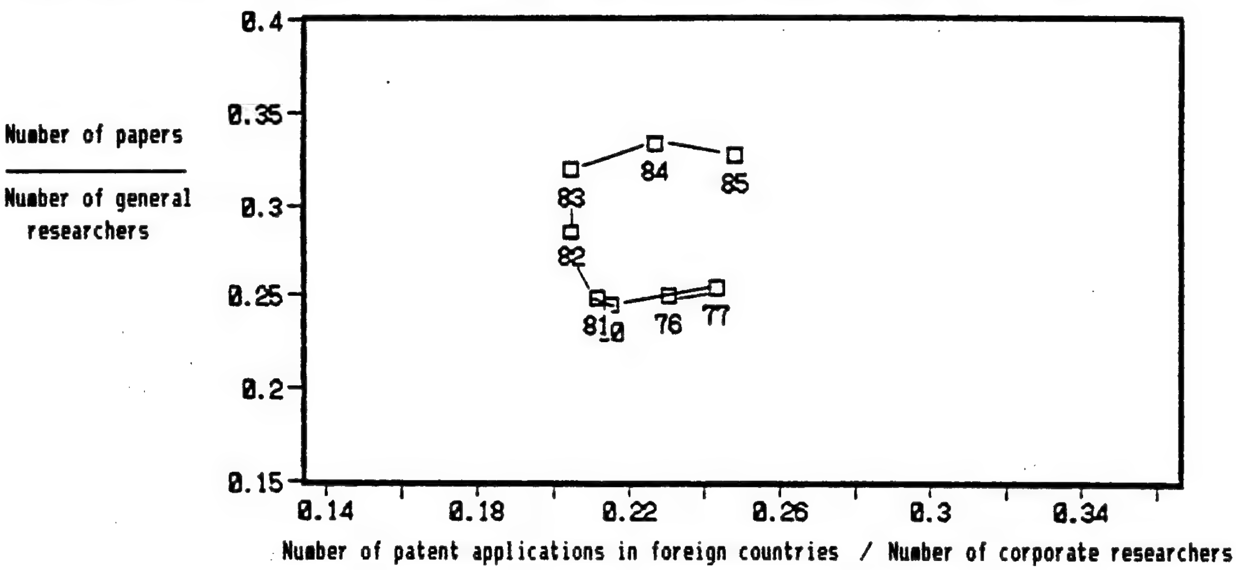
The growth of Japan's productivity in terms of patent applications in foreign countries is great in comparison with the U.S. Conversely, the figure for the U.S. describes a patent-research paper-patent kind of cycle within the range of productivity. If the trends over a slightly longer period could be seen, one could get a grasp on the very interesting state of affairs in terms of the differences in the R&D structures of both countries.

Figure 1-2-24 Japanese Foreign Patent Applications and Papers



* Numbers of applications include EPC applications
* General and corporate researchers are only those in the fields of natural sciences
Data: Investigative Report of Scientific and Technological Research, Management and Coordination Agency
Annual Report of the Patent Office
International Comparative Study of the Numbers of Academic Research Papers, Ministry of Education

Figure 1-2-25 U.S. Foreign Patent Applications and Papers



* Numbers of applications include EPC applications
* General and corporate researchers are include those in the fields of humanities and the social sciences
Data: NSF statistics; Annual Report of the Patent Office
International Comparative Study of the Numbers of Academic Research Papers, Ministry of Education

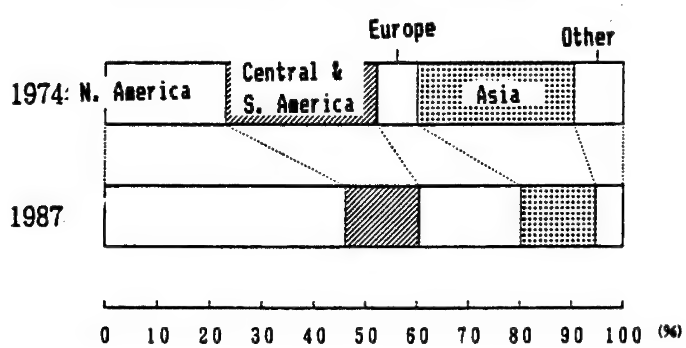
Although we try as best as possible not to hypothesize, Japan's technological developments resulting from the leadership of the private sector and the motivation to apply those developments are much greater than the intellectual property resulting from research papers; in contrast, there is more of a balanced interaction in the case of the U.S. As mentioned before, we would like to carry out a study over a much longer period of time.

1-2-6 Direct Overseas Investments

Direct overseas investments can be used as a reference indicator for assessing R&D strength in terms of international levels. This indicator certainly includes other factors outside of R&D. This is because it is largely prescribed by the ideal of multi-nationalization as the way corporate activities should be.

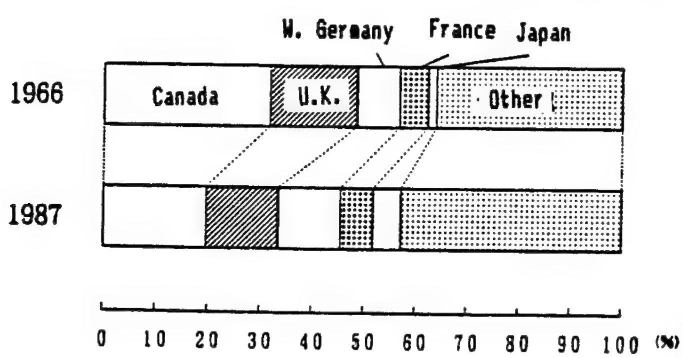
Nevertheless, even if the competitive power of R&D is indirectly related to direct overseas investments, they surely do indicate something. In particular, they are a pre-requisite for analyzing the international structure of R&D.

Figure 1-2-26 Japan's Direct Investments



Data: Actual Direct Foreign Investments Reported, Ministry of Finance

Figure 1-2-27 U.S. Manufacturing Industry's Direct Investments



Data: DOC data

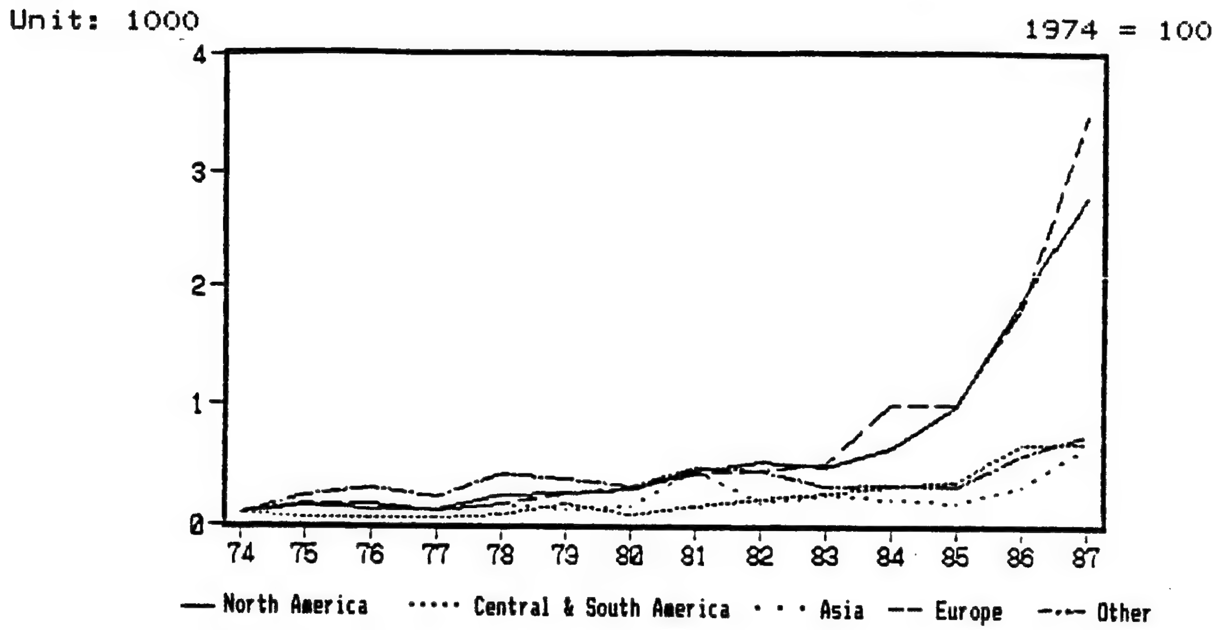
Figures 1-2-26 and 1-2-27 show the changes in the direct investments of Japan and of the U.S. manufacturing industry, respectively. The size of Japan's investments in Asia in 1974 was notable, but about 10 years later the largest share of Japan's investments went to the developed countries of the U.S. and Europe: 46.0% to North America and 19.7% to Europe. This suggests that Japan started to have the power to produce and sell goods in those developed countries, i.e., the technological strength for production and sales. During FY 1988, as shown in Table 1-2-2, the percentage of Japanese investments in North America increased to 47.5%; investments in Europe amounted to 19.4%.

Table 1-2-2 Trends in Japan's Direct Investments

	Number of Cases	Amount	Distribution Ratio
China	170	299	0.6
Korea	153	483	1.0
Taiwan	234	372	0.8
Hong Kong	335	1,622	3.5
Singapore	197	747	1.6
Thailand	382	859	1.8
Malaysia	108	387	0.8
Indonesia	84	586	1.2
Phillipines	54	134	0.3
Oceania	514	2,669	5.7
North America	2,543	22,328	47.5
Europe	692	9,116	19.4
Central and South America	507	6,428	13.7
Africa	74	653	1.4
Middle East	10	259	0.6
Total	6,076	47,002	100.0

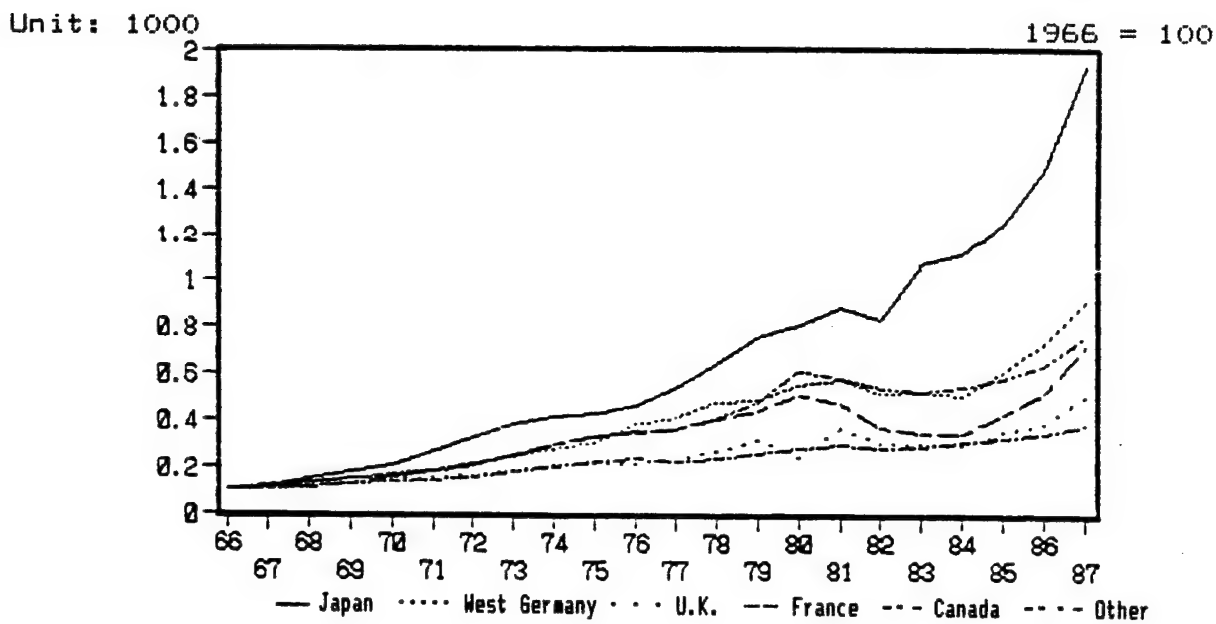
* FY 1988 data * Unit: one million dollars
Data: Actual Direct Foreign Investments Reported, Ministry of Finance

Figure 1-2-28 Changes in Japan's Direct Investments



Data: Actual Direct Foreign Investments Reported, Ministry of Finance

Figure 1-2-29 Changes in Direct Investments of the U.S. Manufacturing Industry's



Data: DOC data

On the other hand, the distribution ratios of the direct investments made by the U.S. underwent great changes, away from primarily Canada and Europe, during the 20 years since 1966. Investments in Canada, especially, receded from 31.7% in 1966 to 19.6%. Investments in Asia, Central and South America, and other European countries, which are classified as "Other," increased in weight, so we can say that worldwide overseas investments were developed.

Figures 1-2-28 and 1-2-29 are a bit more detailed look at the changes in Japanese and U.S. direct investments.

The remarkable increase in Japan's investments in North America and in Europe, and the sudden rise in U.S. investments in Japan from 1980 onwards can be seen. This indicates the deepening inter-dependence between Japan and the U.S.

1-3 Basic Potential Strength of the Developed Countries

1-3-1 R&D Expenditures

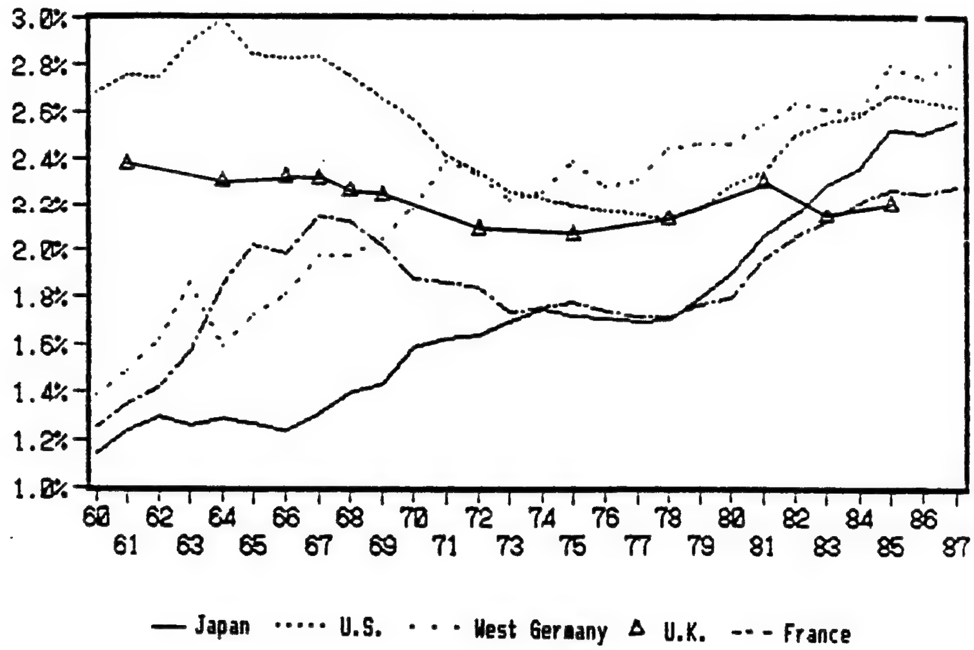
(1) Changes in Percentage of GNP and Shares

A good indicator of the increase in future-oriented R&D strength is R&D expenditures. Also, by conveying the magnitude of investments in R&D from the past up until the present, R&D expenditures also reveal the potential power of R&D.

Figure 1-3-1 shows the changes in the percentage of GNP spent on R&D in the five developed countries of Japan, the U.S., and Europe. Overall, the levels of those percentages remained low or were in a state of stagnation during the 1970's. However, of the changes that occurred after 1960, there was a very remarkable shift in the percentage of its GNP that Japan spent on R&D, despite the fact that it was only for the natural sciences; it rose from 1.1% in 1960 to 2.6% in 1987.

Looking at the percentages of GNP alone, if the humanities and social sciences are included, Japan's 2.80% is second to West Germany's 2.81% and is more than the 2.65% of the U.S. In this sudden change, the increased power of Japan, which may also be described as a unique, basic potential strength that supports its R&D, is suggested.

Figure 1-3-1 Research Expenditures as Percentages of GNP



* Japan's research expenditures are only for the natural sciences; the others include the humanities and social sciences. However, the U.K.'s research expenditures since 1980 are only for the natural sciences.

Data: Japan Annual Report of National Economic Computations, Economic Planning Agency;
Investigative Report of Scientific and Technological Research, Management and Coordination Agency
U.S. International Financial Statistics, IMF; NSF statistics
W. Germany International Financial Statistics, IMF; OECD statistics
U.K. International Financial Statistics, IMF; OECD statistics
France International Financial Statistics, IMF; OECD statistics
Appendices to budget bills

Figure 1-3-2 (A) shows the changes in the Japanese, U.S., and European (British, French, and West German) shares of total R&D expenditures. In 1966, Japan's share was only 4.5%, but by 1983 it grew to about 19%. The share percentage that dwindled greatly was that of the U.S. Figure 1-3-2 (B) shows the shares of research expenditures in 1985 based on the Purchasing Power Parity Theory.

We can probably say that this reveals the relative decline of position of the U.S. as the "world's R&D center." It suggests global changes in the R&D structure.

Figure 1-3-2 Changes in Shares of R&D Expenditures (A)

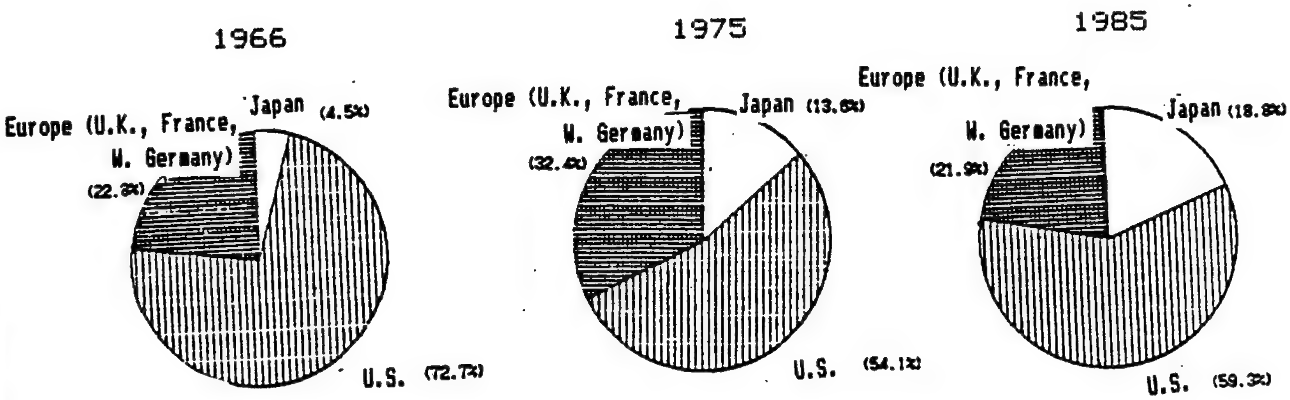
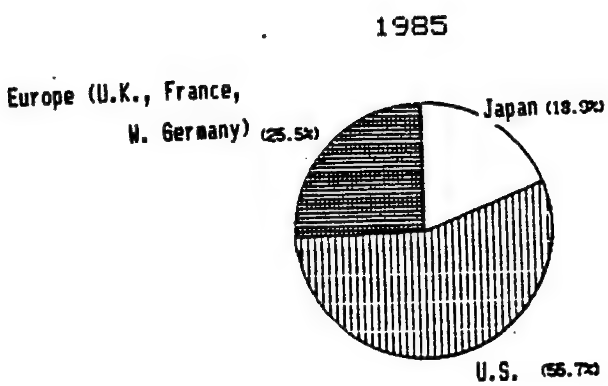


Figure 1-3-2 Changes in Shares of R&D Expenditures (B)



* Japan's research expenditures are only for the natural sciences; the others include the humanities and social sciences.

Data: Research Expenditures	Japan	Investigative Report of Scientific and Technological Research, Management and Coordination Agency
	U.S.	NSF statistics
	Others	OECD statistics
Purchasing Power Parity Theory		OECD Main Economic Indicators 1989

(2) Accumulation of Research Expenditures

It is thought that the magnitude of R&D expenditures accumulated over time is a more suitable indicator of R&D strength than the scale of R&D expenditures for a single fiscal year. We would like to see further studies on this matter to investigate the appropriateness of cumulative R&D expenditures as an indicator.

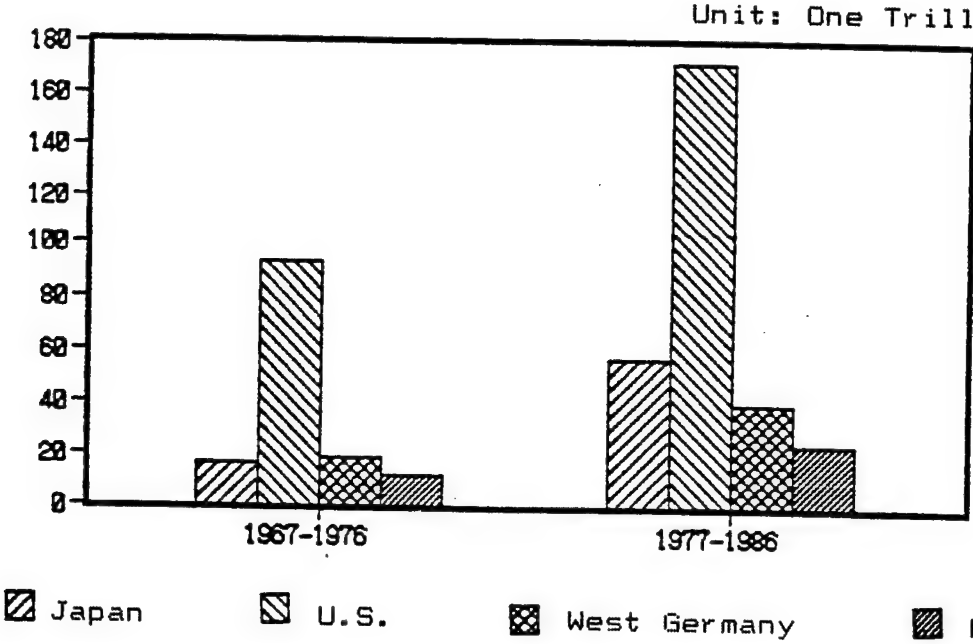
Actual research expenditures in terms of their cumulative amounts over ten-year-long periods, from 1967-1976 and from 1977 to 1986, can be seen in Figure 1-3-3.

The cumulative amount of Japan's research expenditures in the past ten years is more than that of West Germany and France, and the difference with that of the U.S. is shrinking. We may think of it as an extraordinarily large cumulative effect of Japan in the ten years since the latter half of the 1970's.

These kinds of changes are also evident in the research expenditures by nature of the research (Figure 1-3-4).

Figure 1-3-3 Ten-Year-CumulativeAmounts of Research Expenditures

Unit: One Trillion Yen

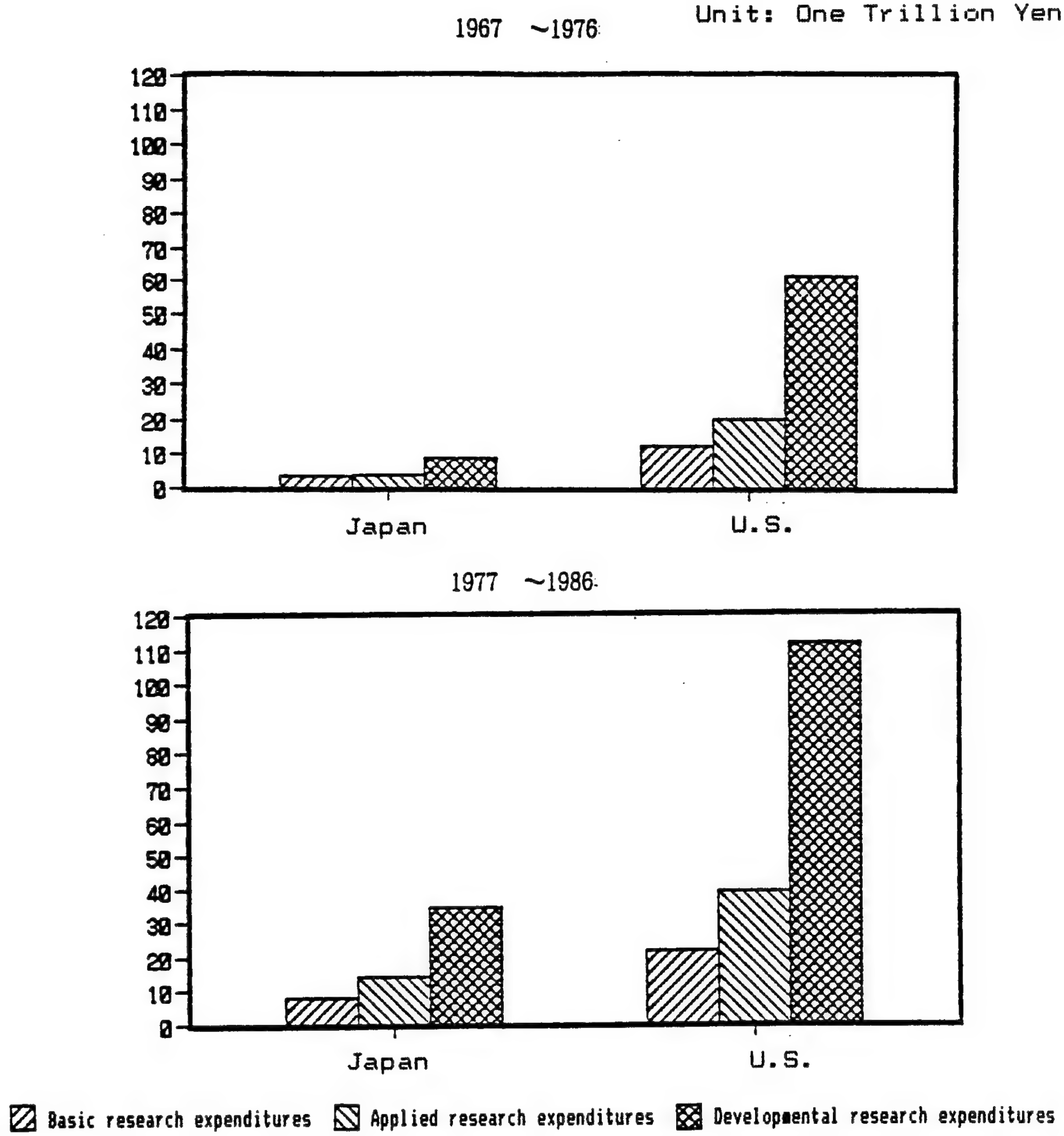


* Japan's research expenditures are only for the natural sciences; the others include the humanities and social sciences.

Data: Research Expenditures Japan Investigative Report of Scientific and Technological Research, Management and Coordination Agency
U.S. NSF statistics
Others OECD statistics

Figure 1-3-4 Ten-Year-Cumulative Amounts of Research Expenditures By Nature of the Research

Unit: One Trillion Yen



* Japan's research expenditures are only for the natural sciences; the others include the humanities and social sciences.

Data: Japan — Investigative Report of Scientific and Technological Research, Management and Coordination Agency

U.S. — NSF statistics

Others — OECD statistics

(3) Research Expenditures Per Researcher

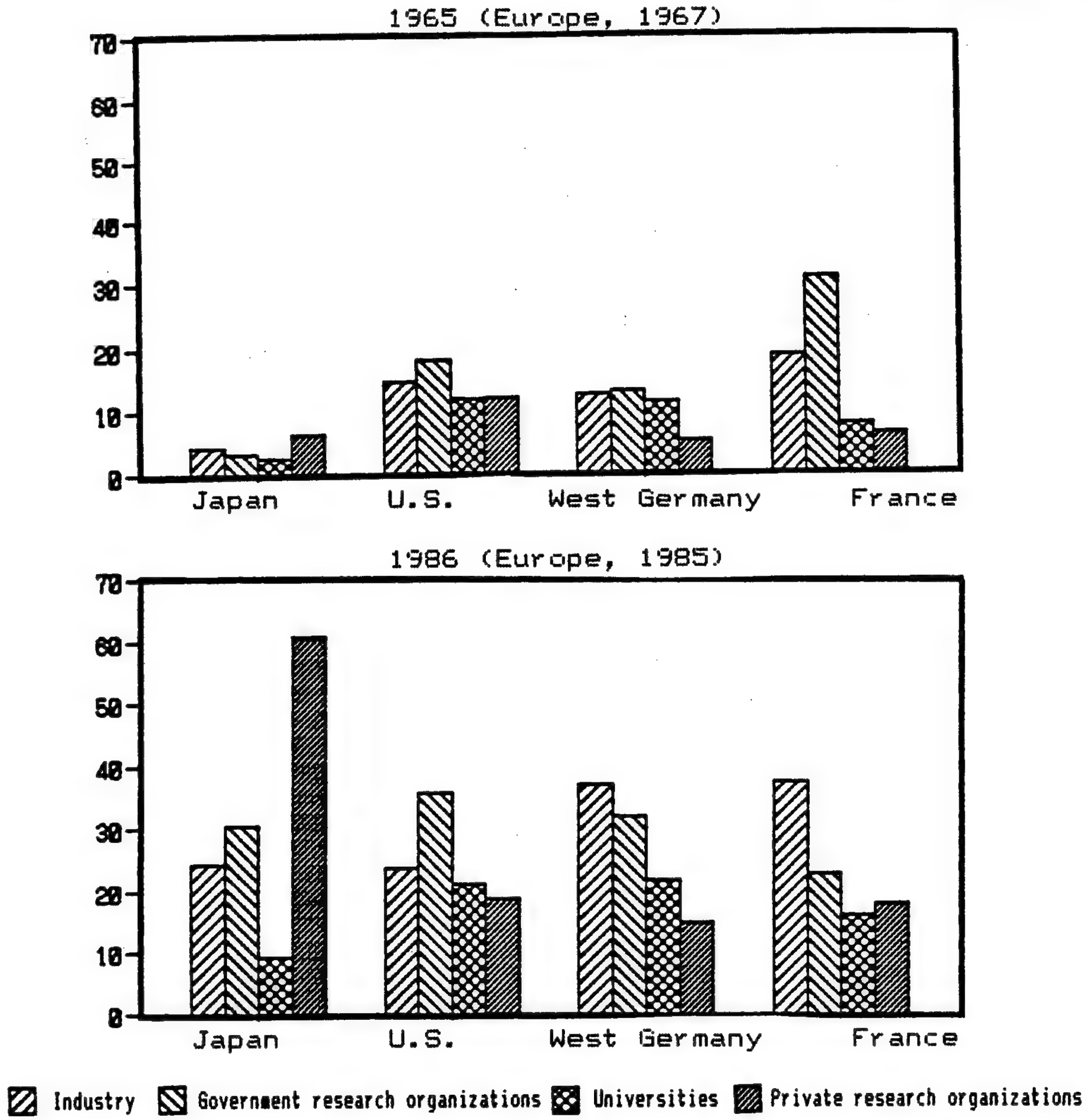
Figure 1-3-5 shows the Japanese, U.S., West German, and French research expenditures per researcher according to the type of organization in which the researchers are employed for the years 1965 (1967 for Europe) and 1986 (1985 for Europe).

During this 20-year period, except for that in universities, the growth in Japan's research expenditures per researcher is very remarkable. The growth of that in private research organizations is especially large and unique.

On the other hand, Japan's research expenditures in universities stands out against that of the U.S., West Germany, and France, and has not come up to those levels. This suggests the issue of Japan's domestic R&D structure.

Figure 1-3-5 Research Expenditures Per Researcher By Employer

Unit: One Million Yen



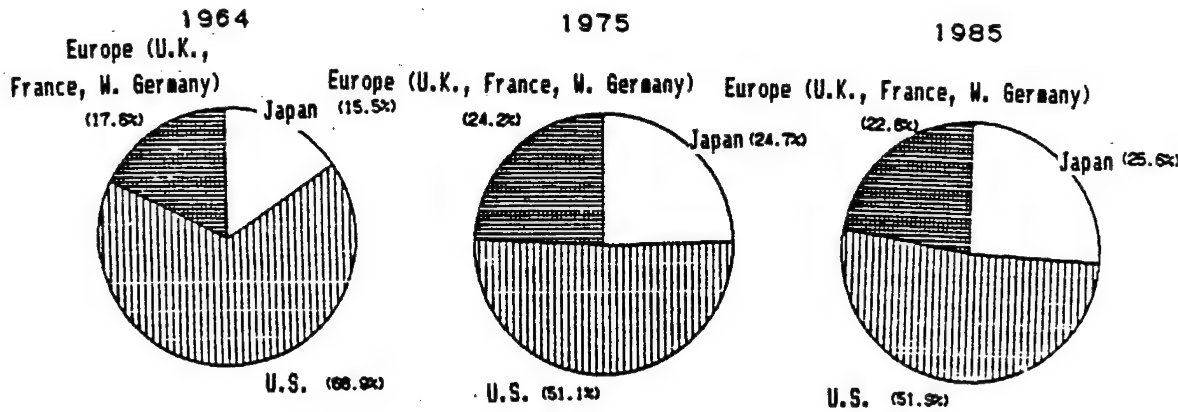
* Japan's research expenditures are only for the natural sciences; the others include the humanities and social sciences.
* Government research organizations are national, public, and special corporate research organs; private research organizations are private non-profit research organizations

Data: Japan	Investigative Report of Scientific and Technological Research, Management and Coordination Agency
U.S.	NSF statistics
West Germany	OECD statistics, "Bundes Bericht Forschung"
U.K., France	OECD statistics

1-3-2 R&D Personnel

Figure 1-3-6 shows the changes in the Japanese, U.S., and European (British, French, and West German) shares of the total number of researchers. In comparison with 1964, Japan's share grew by 10%, and the U.S. share deteriorated by as much as 15%. The relative decline of the basic potential strength of the U.S. that supports its R&D strength is evident.

Figure 1-3-6 Changes in Shares of the Number of Researchers



* Japan's research expenditures are only for the natural sciences; the others include the humanities and social sciences.
* Figures for the U.K. are for industry and private research organizations.

Data:	Japan	Investigative Report of Scientific and Technological Research, Management and Coordination Agency
	U.S.	NSF statistics
	West Germany	OECD statistics, "Bundes Bericht Forschung"
	U.K.	OECD statistics, "Annual Review of Government Funded R&D"
	France	OECD statistics, appendices to budget bills

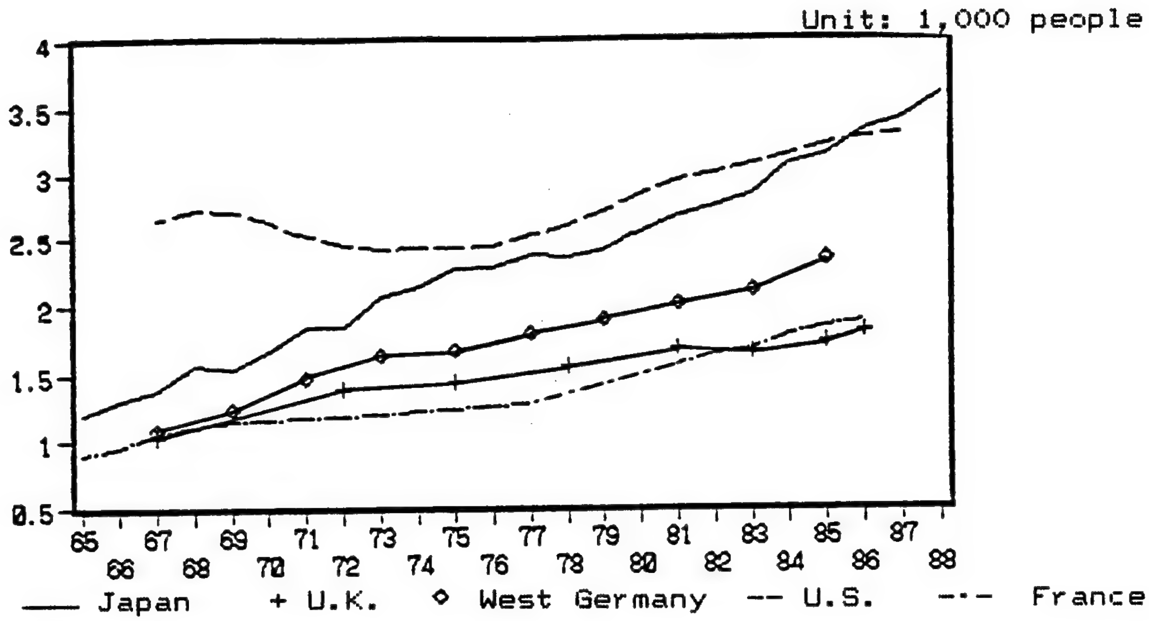
As shown in Figure 1-3-7, in the number or researchers per million population, Japan is already at the same level as the U.S. In Japan's case the increase in corporate researchers is especially noticeable.

There are two points where the Japanese and U.S. statistics on numbers of researchers differ: 1) humanities and social sciences are included in the U.S. statistical values; 2) FTE (full-time employee) conversions were not applied to the Japanese statistics. Then, when a full-time conversion is attempted on a trial basis with data that includes the humanities and the social

sciences, the number of researchers per million population in Japan during 1987 becomes 3,130. (Note)

The number of researchers per million population in the U.S. during 1987 was 3,307. Taking into account the difference in scale of population and other such factors, we can probably say that Japan and the U.S. are already equal in their percentages of research personnel.

Figure 1-3-7 Number of Researchers Per Million Population



* Japan's research expenditures are only for the natural sciences; the others include the humanities and social sciences.
* Figures for the U.K. are for industry and private research organizations.

Data: Japan "Investigative Report of Scientific and Technological Research" Management and Coordination Agency
"Monthly Report on Population Statistics" Management and Coordination Agency
U.S. NSF statistics, "World Population Yearbook" U.N.
"International Financial Statistics" IMF
West Germany OECD statistics, "Bundes Bericht Forschung,
U.K. OECD statistics, "Annual Review of Government Funded R&D"
"British Business", "World Population Yearbook" U.N.
France OECD statistics, appendices to budget bills

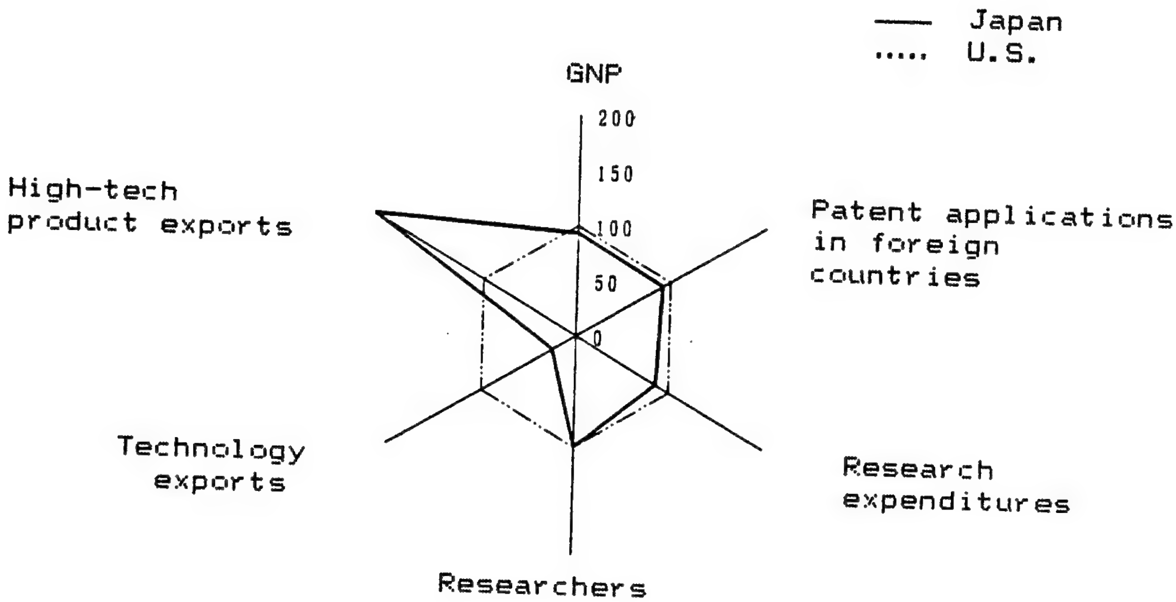
(Note) The FTE coefficients used were 0.815 for corporate and other such researchers and 0.700 for researchers of universities. Refer to the "Study on Methods for Comparing Japan with the Actual State of Statistics Related to R&D Activities in Europe and the U.S." (Future Engineering Research Institute, 1988).
In the OECD's R&D-related statistics, international comparisons were made by halving Japan's R&D employees at universities (a 0.5 FTE coefficient), and the number of researchers in corporations and research organizations was not corrected.

1-4 International Comparisons

The next topic is putting together the comparisons of the developed countries' R&D strength that were examined above. Although there may be various arguments as to what to choose as an indicator for that generalization, here we will try to keep the idea of "population" as the basis for all assessments.

In this study, we have attempted to synthesize per-million-population comparisons. Figure 1-4-1 puts together comparisons of the per-million-population scales of various indicators of Japan and the U.S. in 1986.

Figure 1-4-1 Per-Million-Population Comparisons of Japanese and U.S. Scales (1986)



* Using 100 as the index for the U.S.
* Numbers of patent applications in foreign countries include EPC applications
* For Japan, research expenditures and researchers are only in the natural sciences; for the U.S., humanities and the social sciences are included.

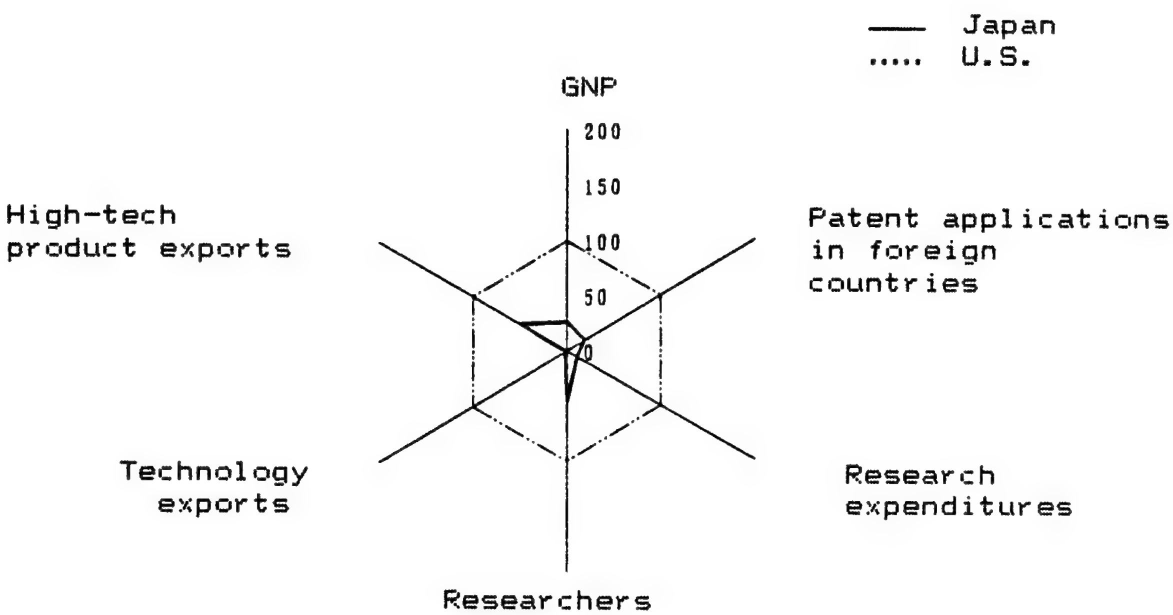
Data: Japan "Monthly Report on Population Statistics" Management and Coordination Agency
"Annual Report of Economic Statistics" Economic Planning Agency
"Annual Report of the Patent Office"
"Investigative Report of Scientific and Technological Research" Management and Coordination Agency
"Science and Engineering Indicators - 1989"

U.S. "World Population Yearbook" U.N., "Annual Report of the Patent Office", NSF statistics
"International Financial Statistics" IMF,
"Survey of Current Business" DOC, "Science and Engineering Indicators - 1989"

In the relative comparison with the U.S. from Figure 1-4-1, Japan lags noticeably behind in technology exports and is slightly behind the U.S. in research expenditures. In high-tech product exports, Japan greatly surpasses the U.S.

Figure 1-4-2 is a another such comparison of the two countries' scales 20 years before. How great the changes are is obvious.

Figure 1-4-2 Per-Million-Population Comparisons of Japanese and U.S. Scales (1965)



* Using 100 as the index for the U.S.
* For Japan, research expenditures and researchers are only in the natural sciences; for the U.S., humanities and the social sciences are included.
* High-tech product exports are based on the U.S. Department of Commerce's (DOC-3) definitions

Data: Same as Figure 1-4-1

Comparisons of one country with another are often made from the viewpoint of the nations' overall power, on a full-scale basis. But, from the scientific and technological viewpoint, and then from the viewpoint of how R&D brings about a wealthier lifestyle and a better social environment for the individual citizen, the natural conditions for the comparisons must be reduced down to a per-person basis rather than in terms of the total population of a country. In doing so, one cannot regard Japan's strength, i.e., its R&D strength, as being that inferior to the U.S.

1-5 NIES and ASEAN Countries At Present

Achieving rapid economic growth, the NIES and ASEAN countries, are steadily building up strength in their R&D and are also about to assume a role as one of the R&D strongpoints in the world of the 21st century. We can certainly say that their strength is a great deal less than that of the developed countries.

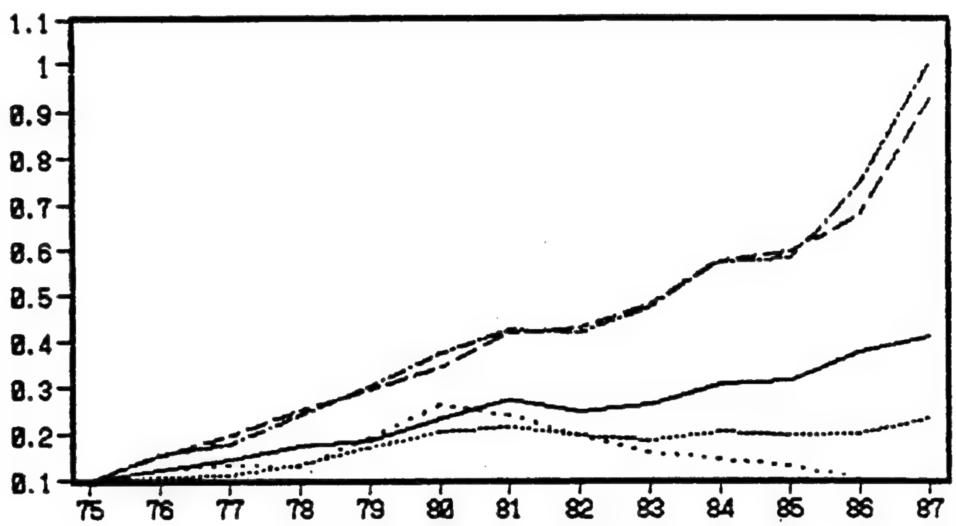
1-5-1 Production and Trade

Figure 1-5-1 is a chronological, relative comparison of the changes in the volumes of exports from Korea and Taiwan, as representive of the NIES, with those of Japan, the U.S., and other countries. Having had an expansion in exports, the percentage of which is much higher than that of even Japan and the U.S., the growth of Korea and Taiwan since 1980 is especially remarkable. Those exports volumes actually amounted to ten times the volumes of 1975. The sluggishness since the 1980's in the countries that export oil, which had been the typical export of developing countries, shows a trend that is in total contrast with that of Korea and Taiwan.

Figure 1-5-1 Changes in Export Volumse

Unit: 1,000

1975 = 100



—— Japan ..... U.S. . . . Oil-exporting countries — — Korea — · — Taiwan

* Oil-exporting countries: Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Oman, Qatar, Saudi Arabia, Arab Emirate Republics, Venezuela

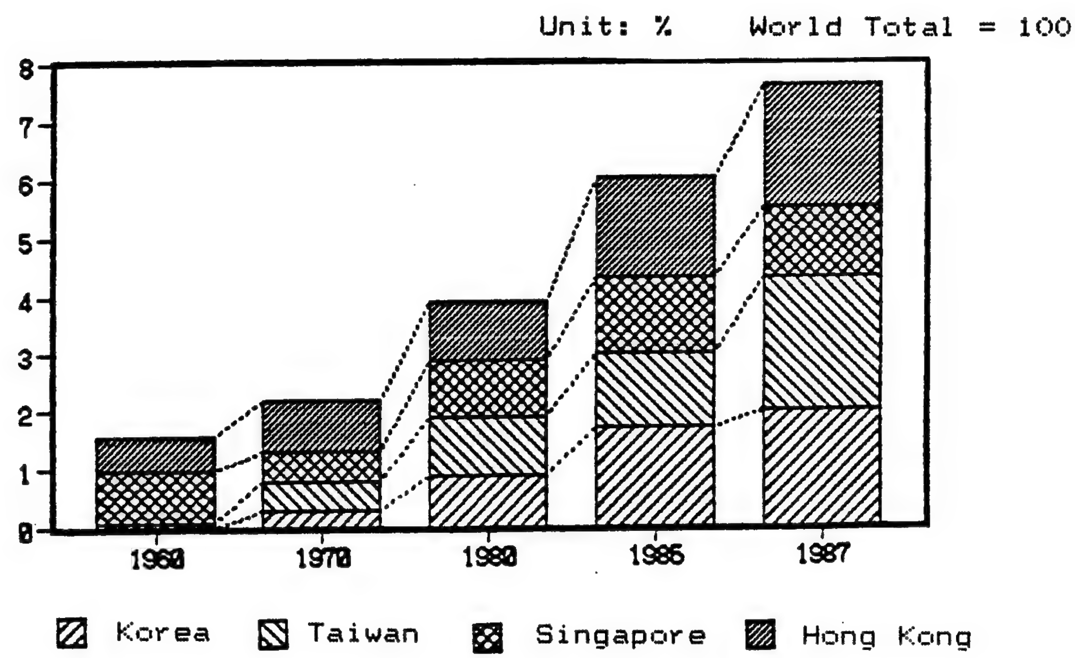
Data: Bank of Japan "International Comparative Statistics"

Figure 1-5-2 shows the changes in the percentage of world export volumes that the four Asian NIES countries account for. In 1987 exports from these four countries amounted to as much as 8% of the world's exports. Also, Figures 1-5-4 and 1-5-5 show the changes in these countries' exports to Japan and the U.S.; the sudden expansion of those exports during the 1980's, especially after 1984, is remarkable.

The volume of these four NIES countries' high-tech product exports to the U.S. increased fivefold over a ten-year period, from $3.5 billion in 1978 to $17.7 billion in 1987, accounting for more than 20% of all high-tech product exports to the U.S. in 1987 ("Science and Engineering Indicators - 1989").

In such a situation, the build-up of the NIES countries' technological strength, which was centered on production technology, and improvements in their R&D strength to support that, is suggested.

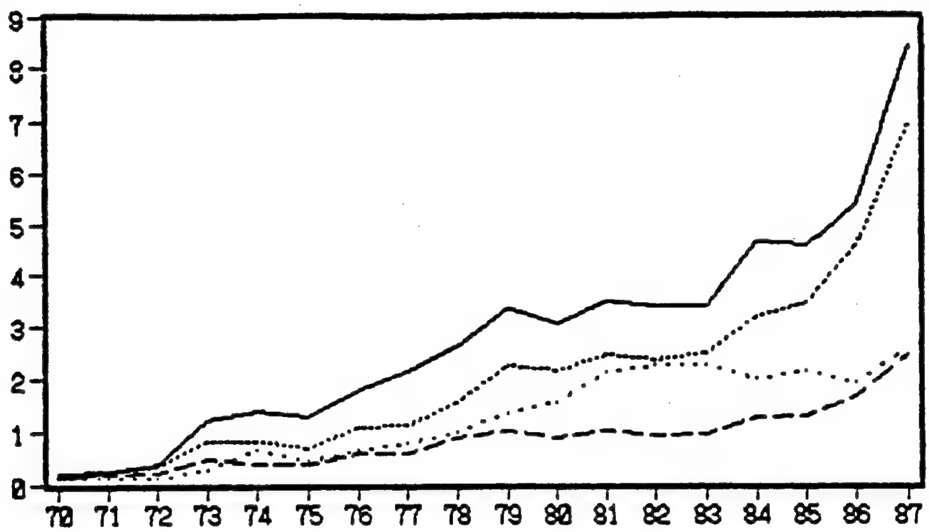
Figure 1-5-2 Changes in NIES Countries' Export Component Ratios



Data: Japan Development Bank "Survey" No. 128

Figure 1-5-3 Changes in NIES Countries' Exports to Japan

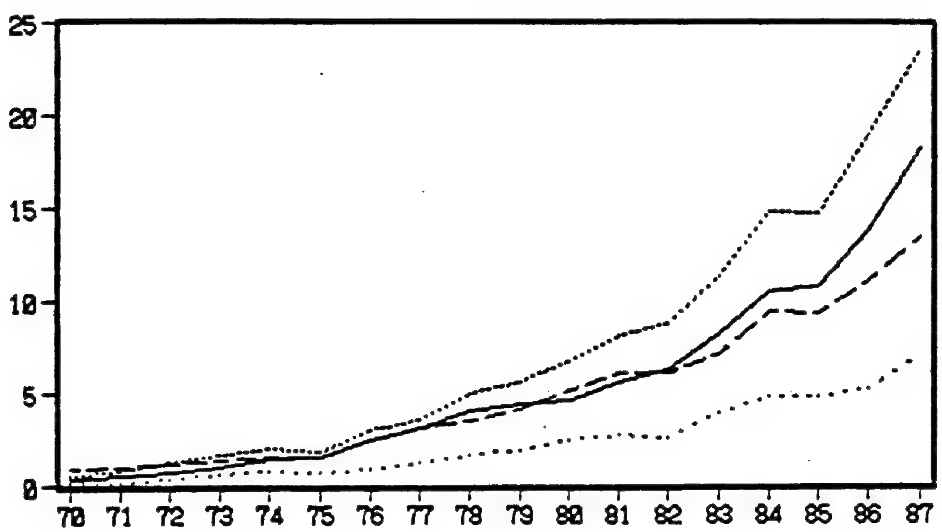
Unit: One Billion Dollars



Data: Japan Development Bank "Survey" No. 128

Figure 1-5-4 Changes in NIES Countries' Exports to the U.S.

Unit: One Billion Dollars



Data: Japan Development Bank "Survey" No. 128

1-5-2 Korea's State of Affairs

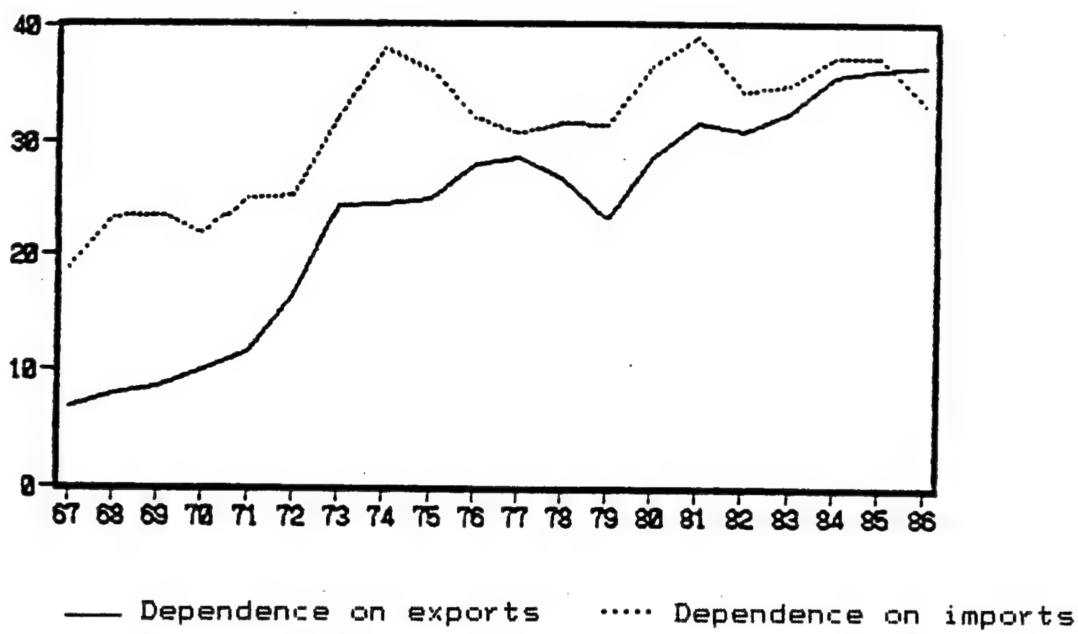
When the focus is on Korea, as the leading country of the NIES nations, we see rapid changes in the domestic structure involving production and trade, and that Korea is striving for economic growth that is bolstered by overseas trade, particularly exports.

(1) Reliance on Exports

Figure 1-5-5 shows how Korea's dependence on trade has changed. In 1986, it exported more than it imported. We can also say that Korea's drive to promote exports is accelerating its economic development and the raising of its S&T standards.

Indeed, Korea's situation is such that it faces a tremendous gap between itself and the developed countries such as Japan and the U.S., and the road that lies ahead will not be an easy one.

Figure 1-5-5 Changes in Korea's Dependence on Trade



* Dependence on exports (imports) = Volume of exports (imports) / GNP x 100

Data: Bank of Japan "International Comparative Statistics"

(2) Introduction of Technology

Figure 1-5-6 shows the state of Korea's technology trade.

It is apparent that Korea's dependence on technology imports is predominant. Furthermore, the degree of that dependence intensified from 1984 through 1986, and there is even a sense of it being a "prototype" of the situation Japan was once in--going from technology imports to product exports. The sources of its imports, as shown in Figure 1-5-7, are mostly in the U.S., followed by Japan. It is no exaggeration to say that the majority of Korea's technology imports are from Japan and the U.S.

Figure 1-5-6 Changes in Korea's Technology Trade

Unit: One Million Dollars

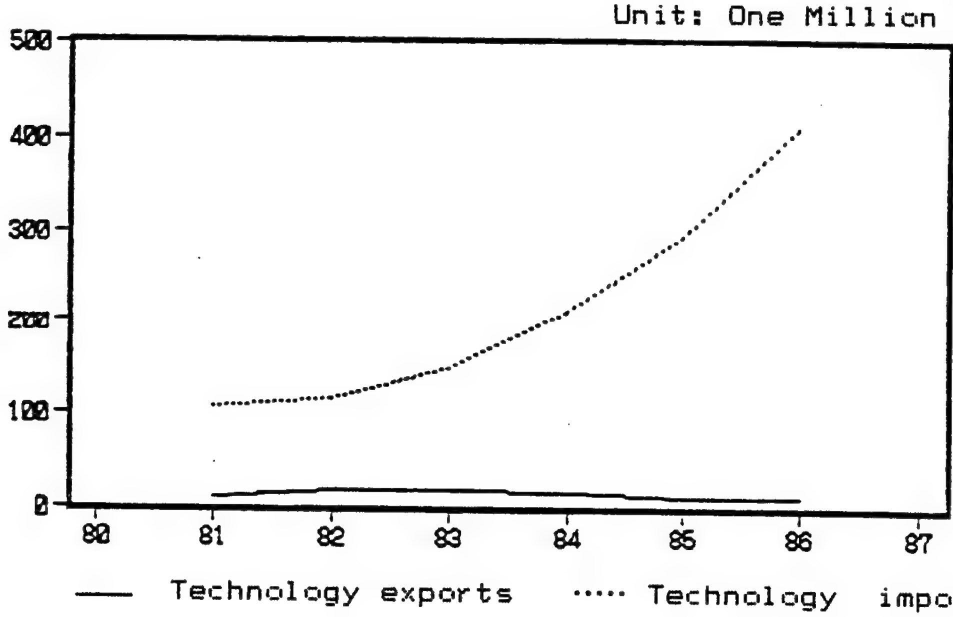
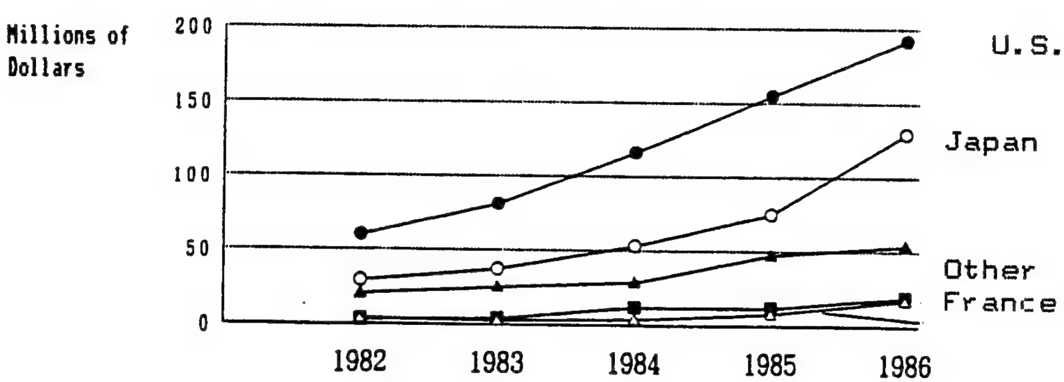


Figure 1-5-7 Korea's Technology Imports



Data: "Korea's Science and Technology Yearbook" 1987

(3) **Foreign Countries' Possession of Patents**

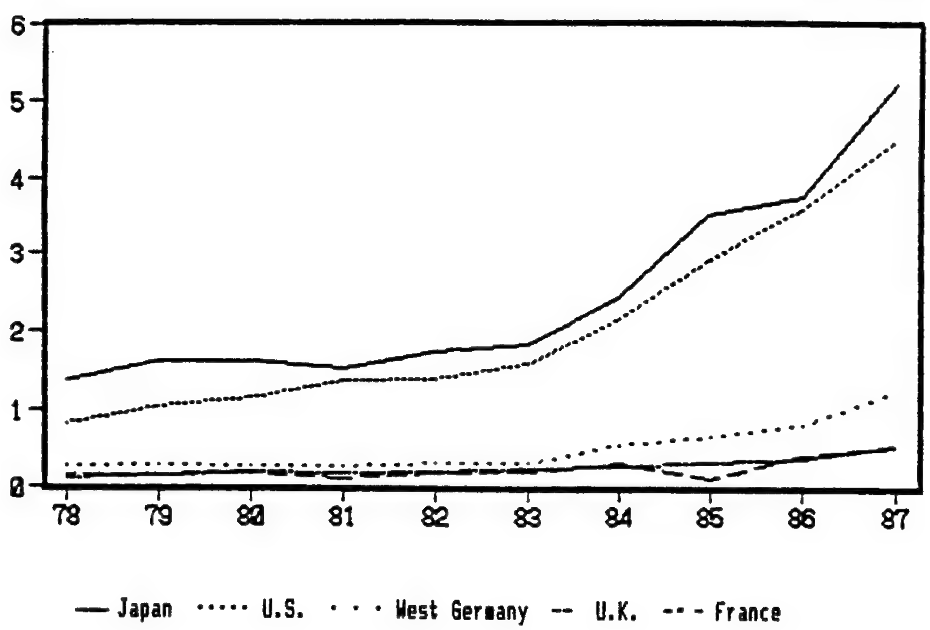
The situation with technology imports is also clearly indicated in the aspect of patents. Figure 1-5-8 and 1-5-9 show the developed countries' patent applications in Korea, and the percentage of Korea's patent applications that were filed by foreigners, respectively. A situation is seen where 70-80% of Korea's patent applications are held by foreign countries. The fact that patent applications by Japan and the U.S., in particular, account for much of those attracts one's attention.

Korea is certainly trying to cope with this situation. It does so by making the most of a utility model system. From the statistics for 1987, there was a total of 18,836 applications for patents and a total of 24,773 application for utility models; moreover, more than 95% of the applications for utility models were from within Korea.

Because this kind of phenomenon could be seen in Japan during the 1950's and 1960's, it is very similar to Japan's past, where it used utility models as a lever in striving to boost domestic R&D strength and to raise the level of R&D.

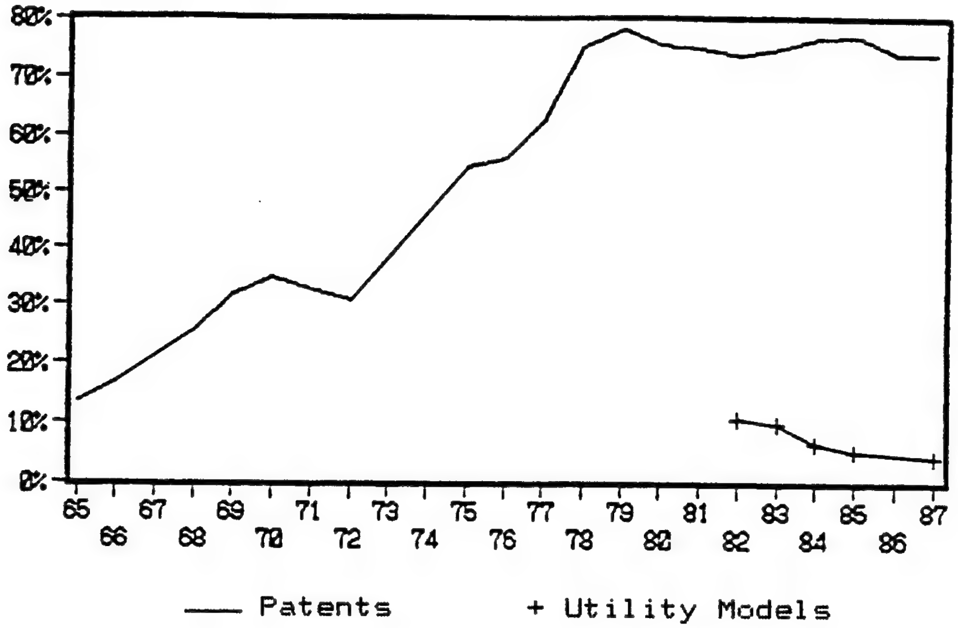
Figure 1-5-7 State of Developed Countries' Patent Applications in Korea

Unit: 1,000 applications



Data: World Intellectual Property Organization

Figure 1-5-9 Percentage of Applications by Foreigners in Korea



* Percentage of patent applications filed by foreigners = $\frac{\text{Number of patent applications filed by foreigners}}{\text{Total number of applications}} \times 100$

Data: World Intellectual Property Organization

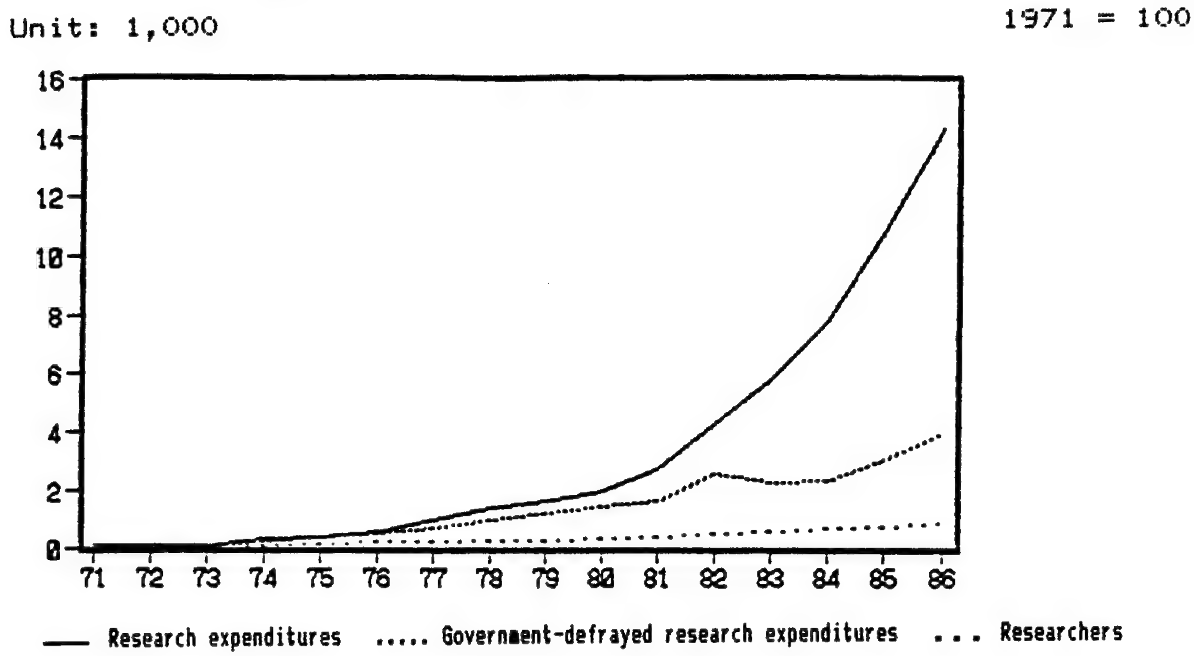
(4) The Rise in Basic Potential Strength

It can be gathered that Korea's basic potential strength, in the form of R&D strength, has been rapidly rising since 1980.

Figure 1-5-10 shows the research expenditures, the research expenditures defrayed by the government, and the numbers of researchers in Korea, using the figures for 1971 as an index. The increase in research expenditures, especially those of the private sector, is striking. Furthermore, there is a great deal of vigor in private research; of the 1.5233 trillion won used for research expenditures in 1986, 1.0217 trillion won, which corresponds to about 70%, was used by the private sector; and R&D based on private leadership is aggressively promoted.

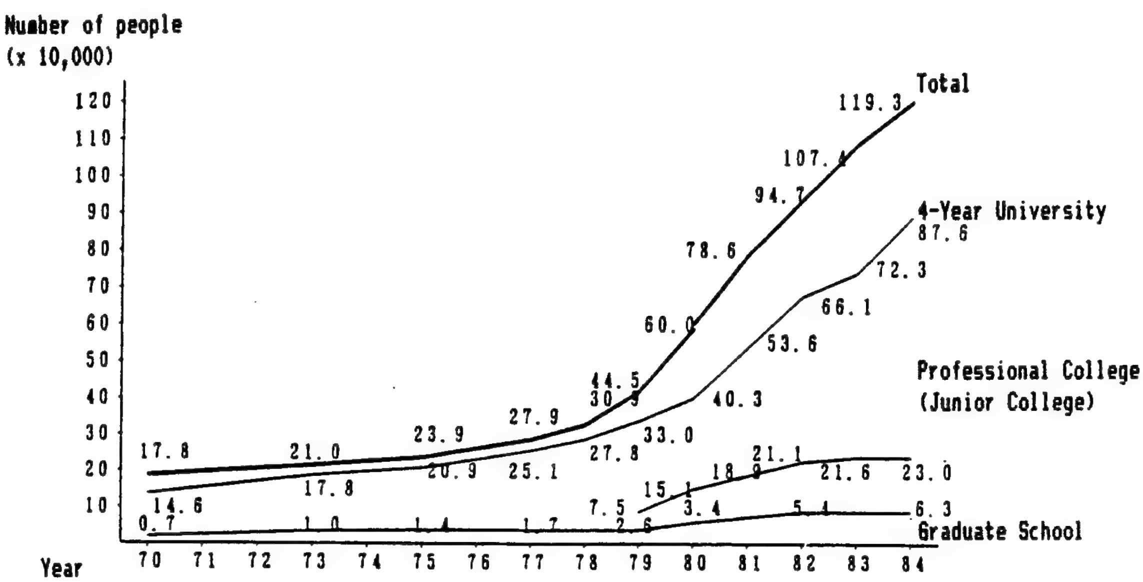
The linking of these kinds of rapid changes to results is probably starting to happen now. Korea's present and future is now gaining attention.

Figure 1-5-10 Changes in Korea's Research Expenditures and Numbers of Researchers



Data: "Korea's Science and Technology Yearbook" 1987

Figure 1-5-11 Increase in Korea's Higher-Educated Population



Data: "Structural Changes in Korea's Higher Education"
University Research Notes No. 69, Hiroshima University, University Education Research Center

1-5-3 Thailand's State of Affairs

Of the ASEAN countries, Thailand is regarded historically and economically, too, as a core country. Its industrial economic growth in recent years in remarkable, and, with the existence of its universities and research laboratories, it is becoming a strongpoint for scientific research in the ASEAN countries.

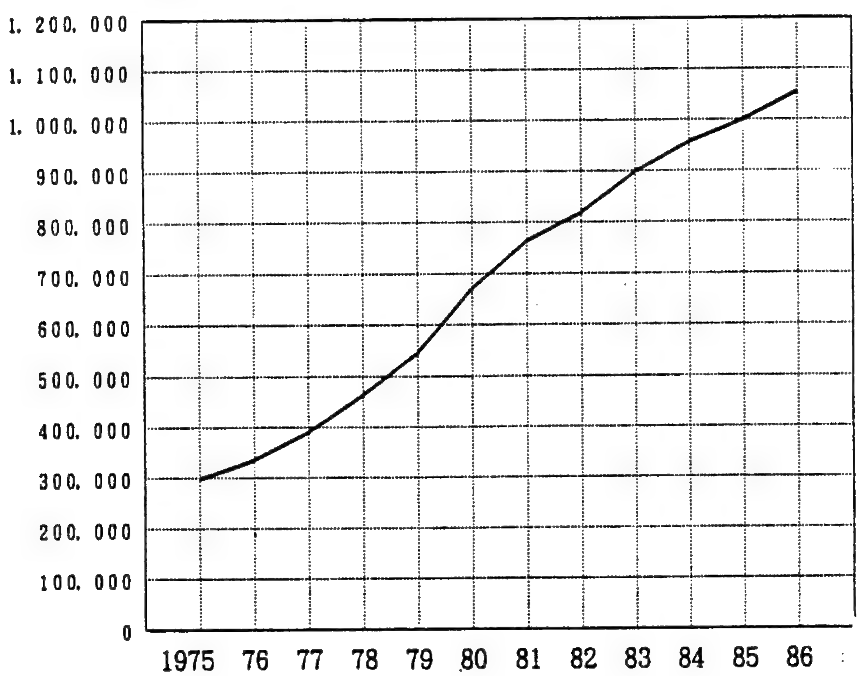
Following after the NIES, the ASEAN countries' present and future scientific and technological development has significance as a model not only for the Asian area but also as a model for the countries of the world that got a late start.

(1) Thailand's Economic Development and S&T

As shown in Figure 1-5-12, the scale of Thailand's economy, despite everything, is growing steadily: the GNP in 1986 expanded to 3.14 times that of 1976.

Figure 1-5-12 Changes in Thailand's GNP

Unit: One Million Bahts



Data: Thailand Science & Technology Indicators 1987

Throughout the 1960's and 1970's, government policies did not hold that much weight in S&T, but the importance of promoting S&T

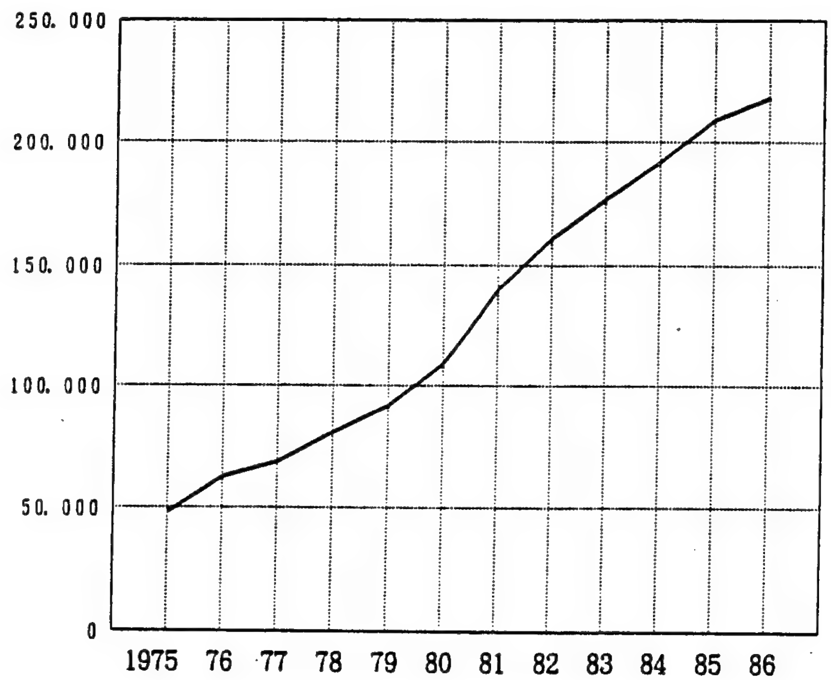
was recognized as a result of the establishment of the Ministry of Science, Technology, and Energy (MOSTE) in 1979.

Thailand is now grappling with S&T promotion as a part of the Sixth National Social and Economic Development Plan for 1987 to 1991.

Nevertheless, the efforts made towards that S&T promotion are not necessarily enough. That is because equipping itself with basic potential R&D strength is aboveall a matter of urgent necessity. The changes in the national budgets and in the S&T budgets also suggest that Thailand is groping for solutions (Figures 1-5-13 and 1-5-14, Table 1-5-1).

Figure 1-5-13 Changes in Thailand's National Budget

Unit: One Million Bahts



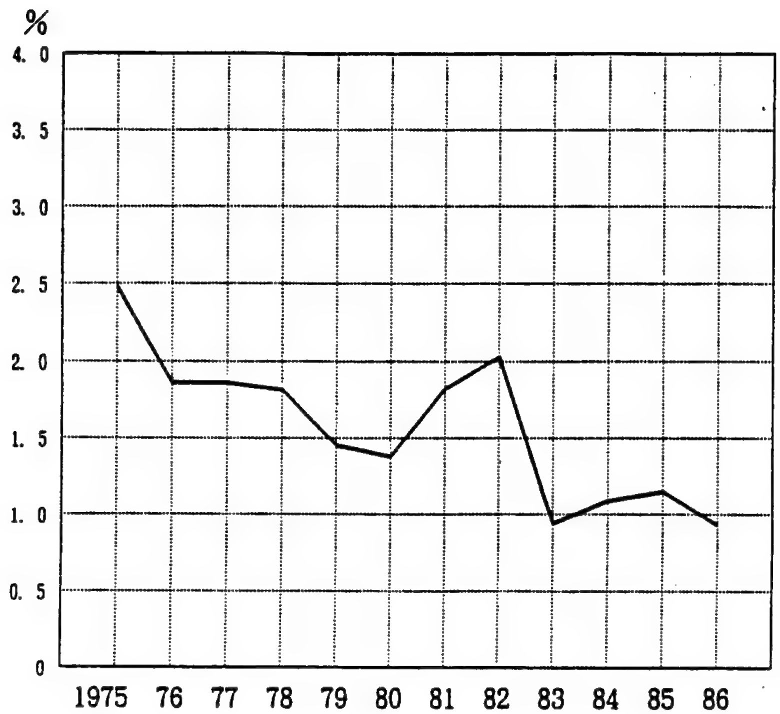
Data: Thailand Science & Technology Indicators 1987

Table 1-5-1 Changes in the S&T Budget (Million Bahts)

Fiscal Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Budget	1191	1166	1277	1468	1331	1507	2549	3271	1656	2104	2416	2020

* The data for 1983 does not include military research expenditures
Data: Thailand Science And Technology Indicators 1987

Figure 1-5-14 Changes in Thailand's S&T Budget Amounts Within the National Budget



Data: Thailand Science & Technology Indicators 1987

(2) Technology Imports and the Patent Situation

In Thailand, too, the introduction of technology from overseas holds a great deal of weight.

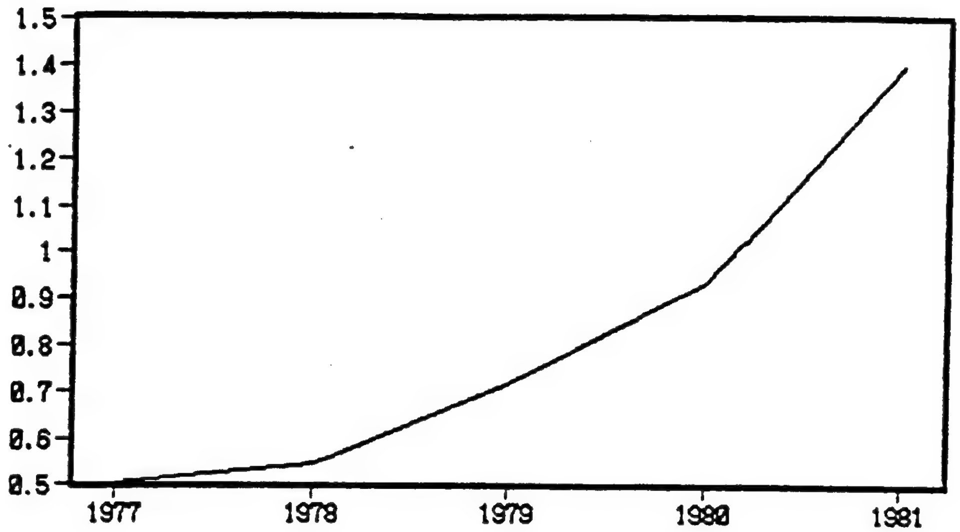
As shown in Figure 1-5-15, the total volume of technology imports, which amounted to 500 million bahts in 1977, increased rapidly after 1980 and reached 2.4484 billion bahts in 1985, as shown in Table 1-5-2.

Because the 1985 S&T-related national budget was about 2.4 billion bahts, nearly the same amount of capital was paid overseas in compensation for technology imports.

We can certainly say that the magnitude of this dependence on foreign countries for technology suggests the current state of affairs in ASEAN countries.

Figure 1-5-15 Changes in Thailand's Technology Imports

Unit: One Billion Bahts



Data: : U. N. Technology for Development

Table 1-5-2 Thailand's Technology Imports

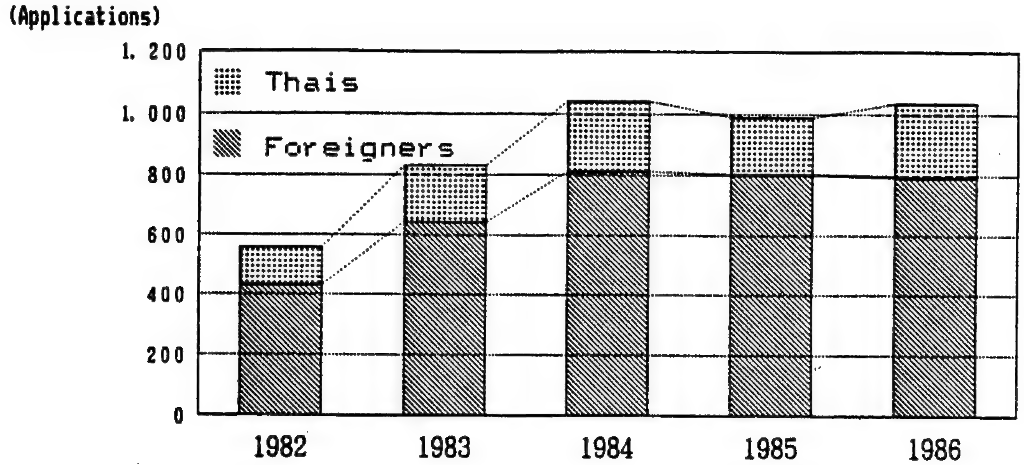
Year	Volume of Technology Imports (Billion Bahts)
1982	1.49314
1983	1.57041
1984	1.99383
1985	2.04484

Data: Thailand Science & Technology Indicators 1987

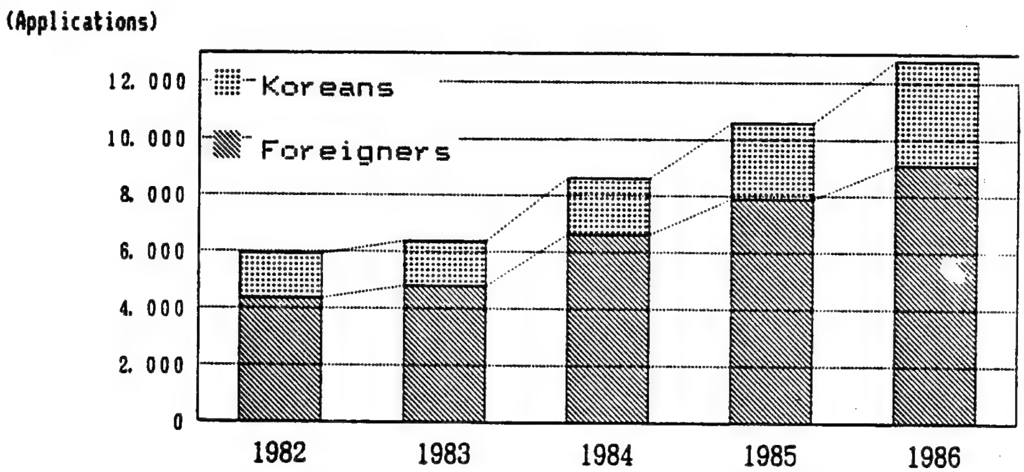
This kind of situation is also clearly suggested in the aspect of patents. As shown in Figure 1-5-16, as much as 80% of the Thailand's patent application were from foreign countries.

This existence of patents enables the introduction of technology from overseas. On the other hand, in the case of Korea shown in Figure 1-5-16, the percentage of Korean applicants is growing little-by-little, and it can be gathered that Korea is attaining the strength to independently develop technology.

Figure 1-5-16 Changes in Thailand's Patent Applicants



(Reference: Korea)



Data: "Korea's Science and Technology Yearbook" 1987

1-5-4 Japan's Handling of the Situation

Indicators in the S&T fields for the Asian NIES and ASEAN countries also signify the changes in those countries' relationships with Japan up until now.

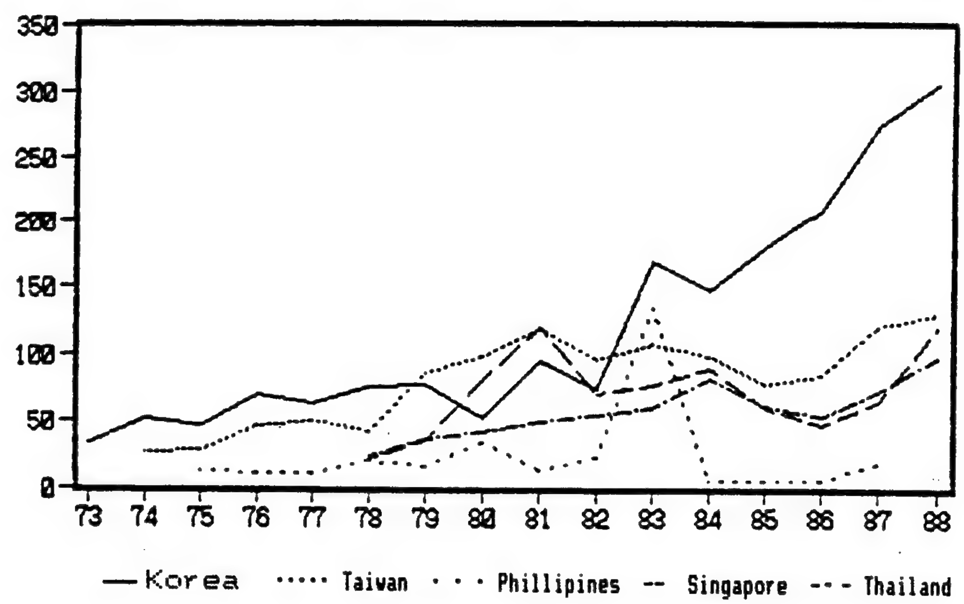
Figure 1-5-17 shows the changes in Japan's technology exports to Asian countries. With 1980 and 1981 as the demarcation, there was a rapid increase in Japan's technology exports to Korea, followed by Taiwan.

Also, Table 1-5-3 shows the relationship between Japan and the Asian countries in terms of patent applications. Although the absolute numbers are small, of all of the Asian countries Korea's special weight increase is remarkable. Patent applications in Japan from Korea are also increasing.

On the other hand, looking at Japan's economic and technical cooperation with the Asian countries in Figure 1-5-18, we can see that private-sector-based cooperation is concentrated in Indonesia, Singapore, and Korea; a great deal of government-based cooperation is with Thailand, Indonesia, and the Phillipines.

Figure 1-5-17 Japan's Technology Exports to NIES and ASEAN Countries

Unit: 100 Million Yen



Data: "Investigative Report of Scientific and Technological Research" Management and Coordination Agency

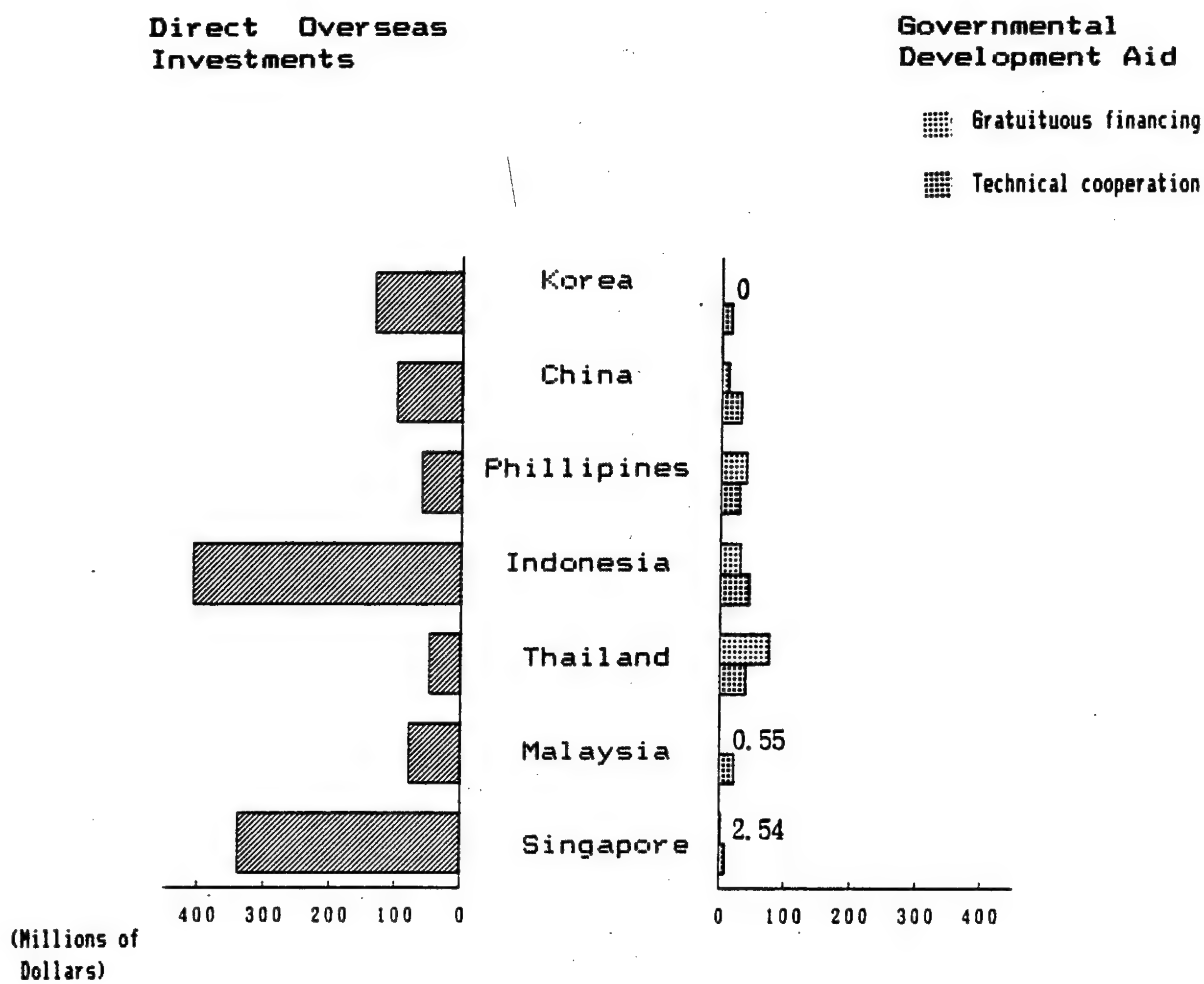
Table 1-5-3 Patent Activities of Japan and NIES & ASEAN Countries

	Japan's certification issues for priority rights to patents				Patent applications in Japan			
	1980	%	1989	%	1980	%	1989	%
Korea	3,087	79.6	9,341	87.9	45	37.2	362	72.0
Taiwan	378	9.7	470	4.4	56	46.3	120	23.9
Malaysia	4	0.1	356	3.4	0	0.0	3	0.6
Phillipines	184	4.7	197	1.9	3	2.5	0	
Indonesia	147	3.8	131	1.2	1	0.8	1	0.1
Thailand	73	1.9	116	1.1	0	0.0	0	
Singapore	5	0.1	9	0.1	3	2.5	6	1.2
Hong Kong	2	0.1	5	0.0	13	10.7	11	2.2
	3,880	100.0	10,625	100.0	121	100.0	503	100.0

* One can see the applications from Japan by the number of priority rights certification issues resulting from the Paris Treaty
* The percent values are the percentages accounted for in the eight NIES and ASEAN countries.

Data: Annual Report of the Patent Office

Figure 1-5-18 Japan's Economic Cooperation with Asian Countries (1985)



* Actual amounts of overseas investments are based on those reported

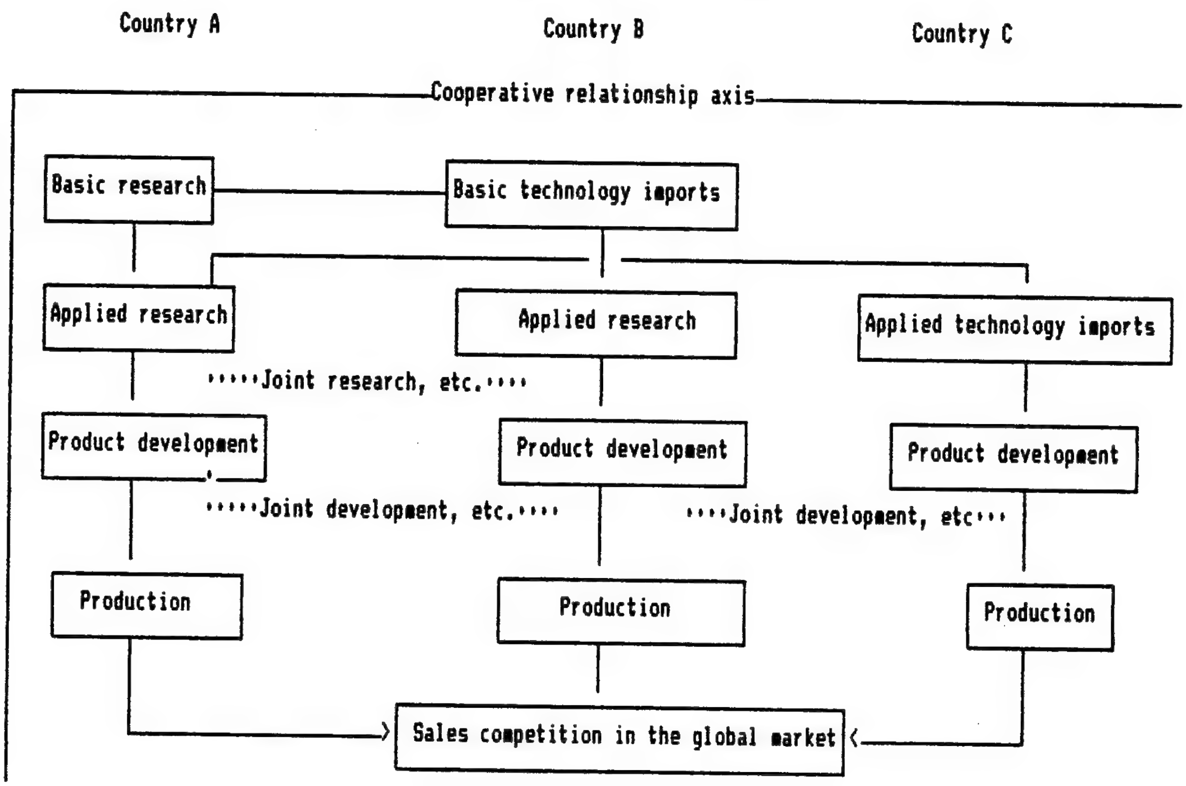
Data: Annual Report of the International Finance Bureau
Development Assistance Committee data

Chapter 2. Growth Processes of R&D Strength and Tracks Left Behind by Government Policies

2-1 A Discussion of Viewpoints and Turning Them Into a Model

In this chapter we will build upon the overall international comparisons of the current state of affairs that were seen in Chapter 1 and will analyze the process of growth in R&D strength within the framework of international competitive and cooperative relationships. We will analyze the structure of the relationships of international rivalry and cooperation with respect to R&D strength in the typical framework shown in Figure 2-1-1.

Figure 2-1-1. Structure of International Competition and Cooperation in R&D Activities



First, assuming a series of processes--basic research, applied research, development, production, sales--we hypothesize countries that implement their own, different styles in these processes. Country A is the type that independently carries out the series of processes and is positioned as the leading country in this framework. Country B is the type that does not conduct research on basic technology at home but rather relies on Country

A for the transfer of technology; however, it is establishes its independence in applied research and subsequent processes. Country C is the type that depends on technology transfer from Countries A and B and is carrying out development and subsequent processes at home. These three types will establish themselves in an economically competitive relationship in the global marketplace. However, when the results of R&D needed to get to that point have the characteristics of being superior international public property, Countries A and B will conduct joint research on the applications of that technology, and all three countries may even collaborate in the development of the technology. In other words, a cooperative relationship is maintained among the three countries as a result of technology transfer and joint R&D.

Whether or not the cooperative relationship axis or the competitive relationship axis affect the process of growth in R&D strength more intensely is probably determined by numerous other variables involving government policies.

Also, if we suppose that the countries corresponding to these three types form an economic block, when that block enters into competitive relationships of a much higher order with other economic blocks, cooperative relationships will probably be reinforced by government policymaking.

On the other hand, when the battle for global market shares gets vigorous, rivalry in R&D activities and competitive relationships will become more actualized, and technology transfer will probably become controlled. Even in the case where, after Country B's research base matures, it starts implementing research on basic technology in its own country and rises from the basic research stage into a competitive relationship with Country A, competitive relationships will probably come to the surface.

The aforementioned is a summary of a hypothetical model of international relationships.

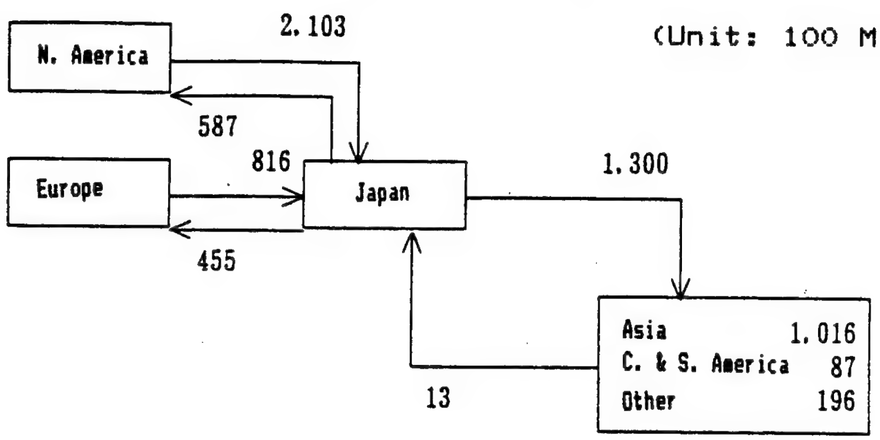
Because the three types of countries shown here are a strictly theoretical model, we cannot completely superpose them directly on a specific country that actually exists. Nevertheless, with regard to the fact that countries having different strategies for their technology do coexist, this model can be thought of as having a certain degree of explanatory power. Then, if this model can tentatively function as an effective explanatory concept, the different processes of growth in R&D strength resulting from these three technology strategies can probably be abstracted in the form of historical stereotypes. Below we will verify these points with examples.

Incidentally, if, focusing on Japan, we look at technology transfer, which is an indicator of the cooperative relationship axis, it is obvious that Japan's relationship with the U.S. is extremely important. As shown in Figure 2-1-2, Japan depends on the North American region for about 70% of its technology imports, even in recent years. On the other hand, as discussed in detail in the previous chapter, in recent years Japan's technology exports to foreign countries are also increasing remarkably, and the weight of its exports to the Asian countries, in particular, is becoming higher.

In the next section we will analyze the processes of the growth of R&D strength in Japan; the U.S., as an example of a leading country with respect to Japan; and in Korea and Thailand, as countries to which Japan transfers technology.

Figure 2-1-2 Structure of Technology Transfer To and From Japan

(Unit: 100 Million Yen)



Data: "Investigative Report of Scientific and Technological Research" Management and Coordination Agency

2-2 Each Country's Process of Growth in R&D Strength and Tracks Left Behind by Government Policies

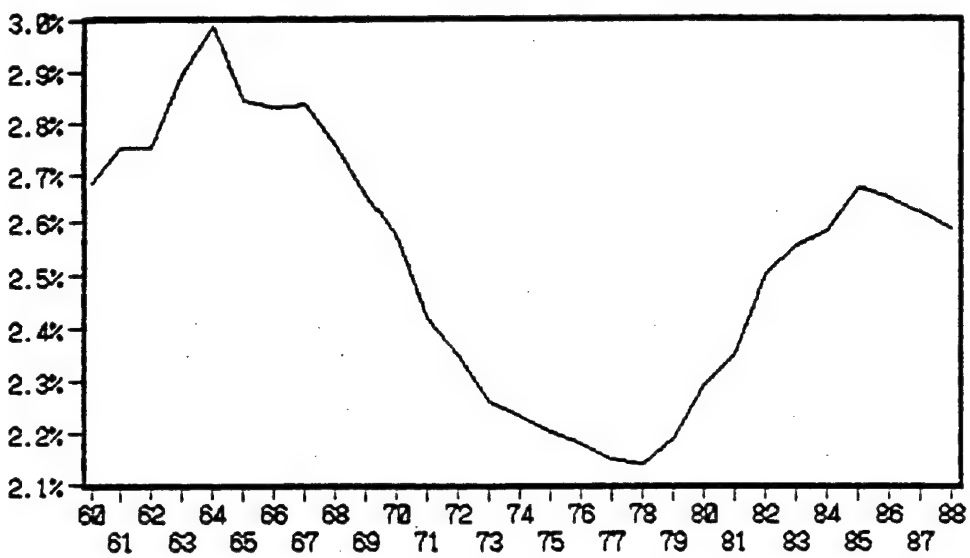
2-2-1 The U.S. Process

The prinicipal player in the greatest reconstruction of the Western countries after the war, the U.S. long held the position as a leader building a new world order. In S&T fields, as well, the U.S. took the lead in post-war technological innovation by making the most of its abundant natural resources and its human resources, which built up as a result of government policies that enabled an influx of excellent scientists and technicians from Europe and Asia. It is common knowledge that the U.S. was

primarily the birthplace of the technological innovation in the 1950's and 1960's that is called "the third industrial revolution." In the 1970's, however, that technology development power entered into a period of stagnation, and the number of prominent technological innovations also declined.

According to Masanori Yoshimi (Note 1), from the aspect of government policy-making, this technological evolution of the U.S. passed through three transitional periods. The first was when, in the middle of an intensifying cold war relationship between the U.S. and the Soviet Union after World War II, the Soviets were the first to launch a satellite into space. The so-called "Sputnik Shock" was a turning point: the U.S. put space development policies at the center of R&D; the introduction of a systematic R&D system and huge investments of capital and personnel commenced; the U.S. went as far as to succeed in mankind's first landing on and exploration of the moon in 1969. The second shift in policies started with the government's taking a second look at the "Big Science" resulting from such tremendous investments of capital. The government's involvement in R&D led to reductions in primarily the budget for space development; during the 1970's it resulted in a nearly invisible increase in real government outlays for research expenditures. The third shift in government policies was when the Carter administration went back again to fortifying government assistance towards R&D

Figure 2-2-1 Changes in Growth Rate of U.S. Research Expenditures Measured as Percentages of GNP



Data: Science & Engineering Indicators NSF

activities. The Reagan administration also followed along the same route, resulting in R&D intensification policies being more expressly incorporated into policy programs.

The effect on the overall levels of R&D activities that these kinds of shifts in U.S. technology policies had are conspicuously evident in the R&D expenditures as a percentage of GNP, shown in Figure 2-2-1. The percentage of GNP was at a level of about 2.8% at the end of the 1960's; it showed a consistent downward trend during the 1970's; by the 1980's it began to rise again. Although the percentage was declining after 1986 or thereabouts, it was still at a high level in comparison with the 1970's.

As mentioned above, a salient feature of U.S. R&D activities is in the point to which they have been led by the government's S&T policies. Next we will analyze in more detail the government's involvement in R&D activities.

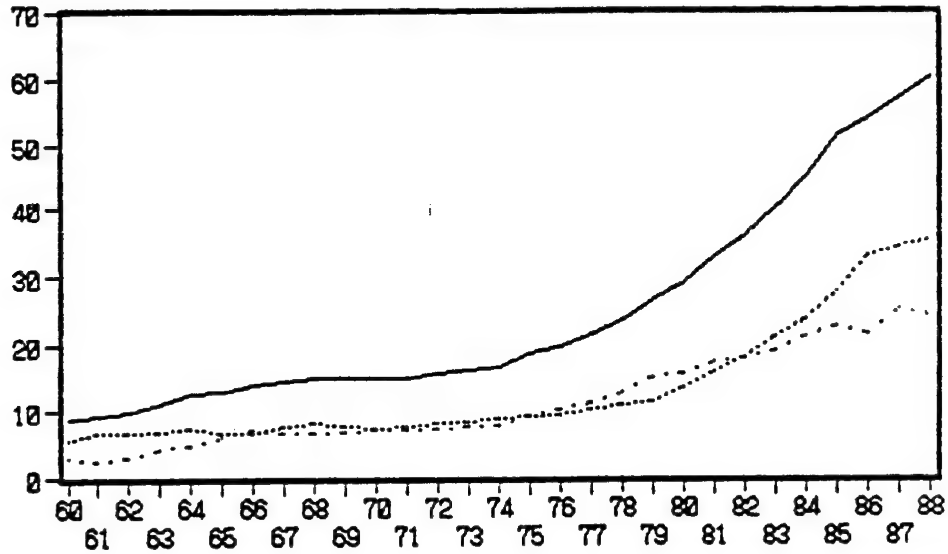
The Federal Government defrayed about 47% of all of the R&D expenditures in the U.S. in 1984. Although this percentage that the government bears is tending to decline over the long term, the value of 47% is a high level in comparison with other developed countries. Furthermore, we can understand how the organization bears a leadership role domestically: about one fourth of the government's share of R&D expenditure was used within the Federal Government and the rest was disbursed as grants and commission fees to corporations, universities, and research organizations.

What is more remarkable about the make-up of government outlays for R&D is the noticeably high percentage of basic research expenditures that are born by the government. In 1984 the government defrayed more than 65% of the costs of basic research, and the amount used inside the government was no more than one fourth of the total amount of its defrayments. In other words, it is obvious that the government sector has an extremely important function in maintaining the expenses for high-risk basic research. As government support for basic research, assistance through the NSF and NIH, in particular, has come to fulfil a great role. Through the results of basic research, that support by the NSF and NIH has extended a widespread effect on the world's S&T. We can probably evaluate this as one of the factors that enabled the U.S. to take the lead in post-war technological innovation (Note 2)

That DOD-related budget amounts account for a very high percentage of government-defrayed R&D expenditures also stands out, as shown in Figure 2-2-2. This can also be seen in the U.S. government's own comparison of Japan and the U.S., shown in Figure 2-2-3.

Figure 2-2-2 R&D Budgets of the U.S Government

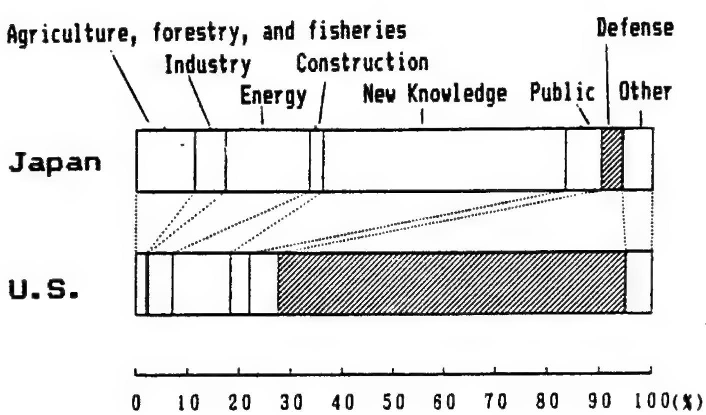
Unit: One Billion Dollars



—— Total R&D Budget ..... Defense R&D Budget ... Other R&D Budget

Data: Science & Engineering Indicators NSF

Figure 2-2-3 Government-Defrayed Research Expenditures By Objective (1985)



* "New Knowledge" includes general research in universities, but does not necessarily indicate basic research.

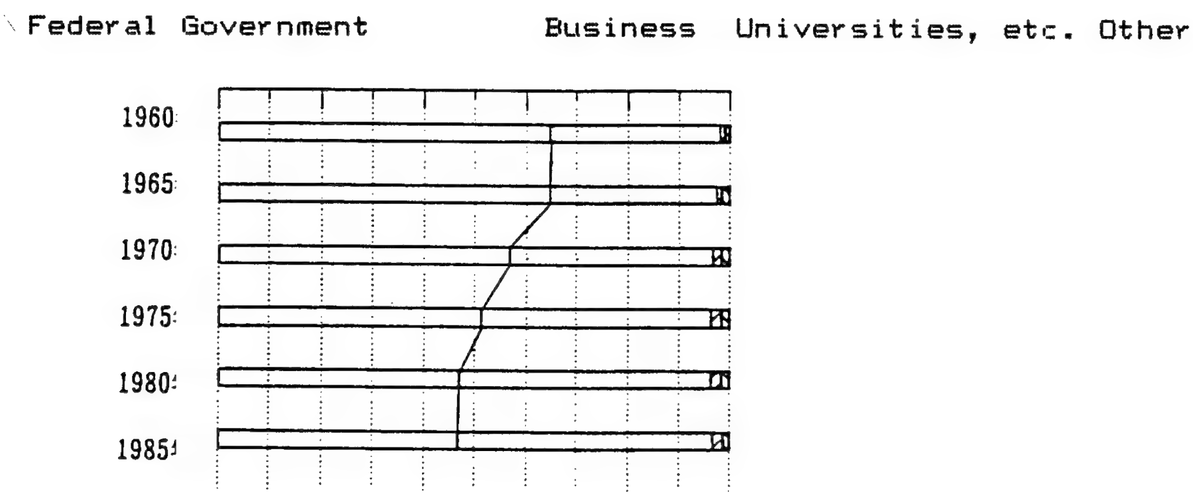
* 1985 data

Data: The S&T Resources of Japan NSF

Takahira Wakasugi (Note 3) points out that in weapons-related programs, which account for 70% of the Pentagon's R&D budget, participation in private enterprises' R&D is negative because the spillover into commercialization of the developed technology is difficult. On the other hand, although general R&D programs account for a small percentage of budget amounts, they characteristically form the basis for commercialized technology and are significant as a way of fostering private-sector R&D. Examples of these in recent years include projects that are closely related to high-tech fields: the VHSIC (Very High Speed Integrated Circuit) project, software technology, advanced materials development, supercomputer projects, gallium-arsenide semiconductor development, etc. The private sector has been actively participating in government R&D in such fields.

Although government-defrayed research expenditures have this kind of important support function, since the end of the 1960's they have been levelling off as a consequence of the previously mentioned shifts in government policies. As shown in Figure 2-2-4, the government's share of R&D expenditures fell from about 65% in the 1960's to about 50% in 1975.

Figure 2-2-4 Component Ratios of Research Expenditures in the U.S. By Source of Defrayment (%)

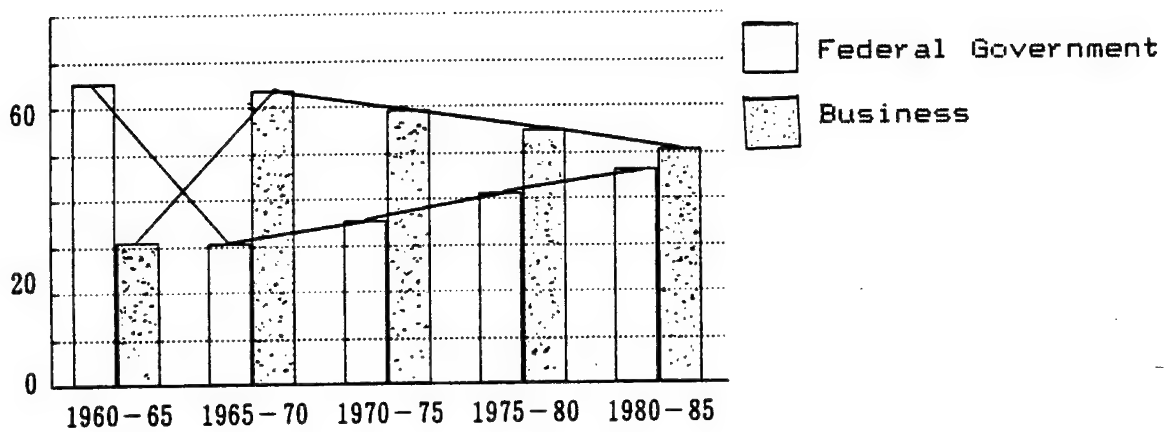


Data: N S F "SCIENCE INDICATORS"

By looking at the extent to which the different sectors contribute towards the growth of R&D expenditures, the structural changes resulting from changes in the government's share of defrayments become clearer. According to Figure 2-2-5, which shows the scope of contributions from the government and private

sectors, since the latter half of the 1960's there was a drastic reversal in the sizes of contributions from those sectors. That the scope of government contributions was influenced by the Reagan administration, which increased defense R&D expenditures by more than 200% during the five years after 1980, is also evident from this diagram.

Figure 2-2-5 Degree of Contributions Towards the Increase of R&D Expenditures in the U.S. By Source of Defrayment (%)



Note: Data from "SCIENCE INDICATORS" was calculated using the formula below. If R is the total amount of R&D expenditures, and R1 and R2 are R&D expenditures from each source, then the rate of increase from a previous period, t-1, to the present period is:

The point that the overall level of R&D activities remained sluggish when the leadership of the government sector diminished in this way during the 1970's was already seen. Meanwhile, externally, the U.S. maintained its position as a leading country in the free-market economic sphere, during the 1970's as well, thanks to the R&D stock that it had built up as a result of government-led technology policies up until the first half of the 1960's. Recently, however, because the international competitive strength of other countries, starting with Japan, is increasing, the U.S. is forced by necessity to develop new government policies for boosting its own R&D strength.

The Carter administration decided that accelerating R&D activities was essential for the recovery of U.S. industry's international competitive strength; it pushed for reforms of the patent system and the tax system pertaining to R&D. The Reagan administration that started in 1981 basically followed suit in R&D promotional policies. However, policies from the Reagan administration were based on the principle of leaving private-sector R&D activities up to market principles and were not the kind of policies as those in the past that involved strengthening assistance. The Economic Recovery Act of 1981 had the effect of large taxbreaks for R&D activities but reduced annual expenditures for direct aid; qualitatively, it spelled out up front the goal of building up military strength. As mentioned before, the private sector could not become active in these R&D activities with military objectives; whether or not the Reagan administration's technology policies could have enough effectiveness is a delicate subject.

Notes 1. Masanori Yoshimi "Japan's Industrial Technology Policies" 1985
2. For more about this concrete data, refer to the Future Engineering Research Institute's "Study on Methods for Comparing Japan with the Actual State of Statistics Related to R&D Activities in Europe and the U.S." 1988
3. Takahira Wakasugi "Economic Analysis of Technological Innovation and R&D" 1986

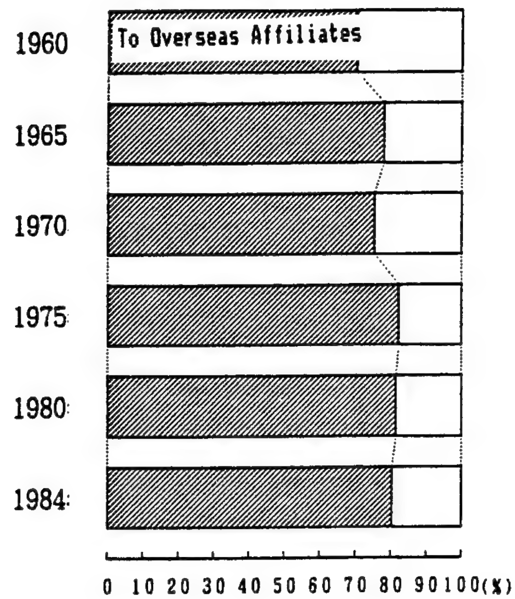
In grasping the growth process of R&D in the U.S., an inpenetratable point along with the contribution of government R&D policies is the multi-national development in the private sector. This is considered to be a premise of U.S. R&D strategy.

This presumed basis of R&D strategy is clearly shown in the technology exports of the U.S., which holds the leading position among the developed countries. As the structure of technology exports shown in Figure 2-2-6 reveals, 80% of the export partners are affiliated companies overseas; in the mid-1960's, exports to affiliated companies already amounted to more than 70%.

Adequate consideration should be given to the point that this global development of the private sector is structuralized together with the basic research of the Federal government and the military research leadership.

To the U.S., the development of a multi-national private sector and technology transfer from the U.S. to overseas affiliates played a great role in post-World War II reconstruction and in

Figure 2-2-6 Structure of U.S. Technology Exports



Data: "Survey of Current Business" DOC

the industrial recovery of Europe and then Japan. In Europe, especially, the extent of those contributions was large.

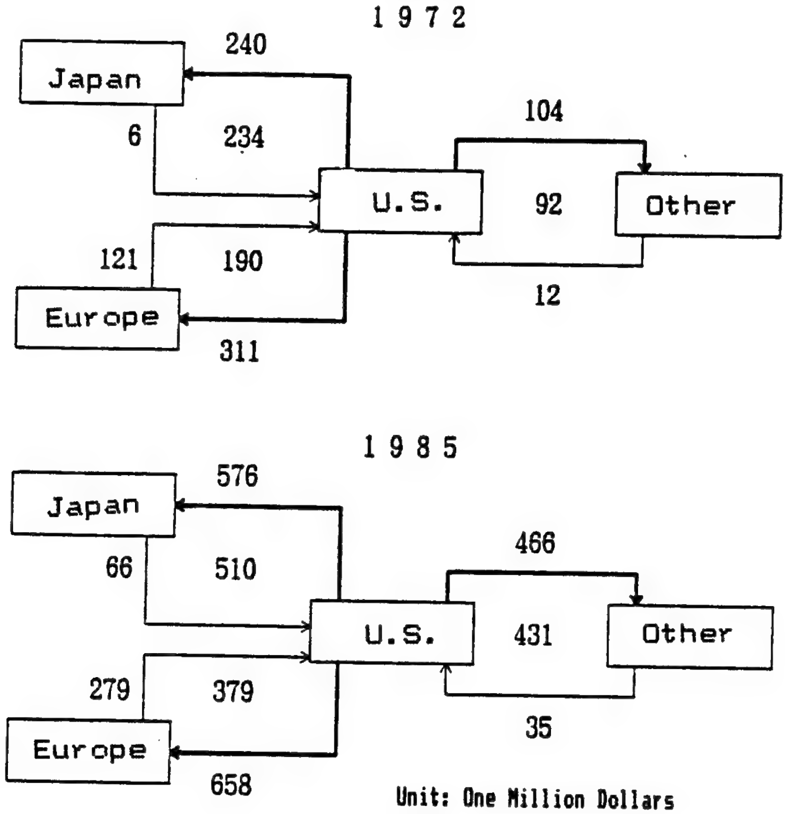
This multi-national development due to the U.S. has also had a great influence on the South and Central American regions.

The relationship with Japan was a bit peculiar. As shown in Figure 2-2-7, if technology transfer transactions with overseas affiliates are excluded, the large weight of the value of technology transfer from the U.S. to Japan is clearly evident.

Looking at the correspondence with Figure 2-1-2, we can see that the U.S. has behaved nobly towards Japan as an overwhelmingly powerful technology-providing country, and that to Japan, with that alone, the weight of its relationship with the U.S. is staggering.

Then, in the latter half of the 1980's, Japan emerged as the U.S.'s greatest technology rival. That is because, as seen in the previous section, Japan is maintaining a nearly equal position as that of the U.S. in the relative comparison of their R&D strength.

Figure 2-2-7 Structure of Technology Transfer To and From U.S.



Unit: One Million Dollars
Data:
* Transactions with affiliated companies excluded

Here, in the S&T policies of the U.S. the shifts of the Reagan and Bush administrations come to visit. The Federal Government's S&T support policies, which are centered on military research as a result of the Reagan administration, have effected a recovery of the vitality of receeding U.S. industrial technology, and, as a global strategy, they have started to shift in a direction for coping with the post-cold-war structure.

Those policy requirements are the following:

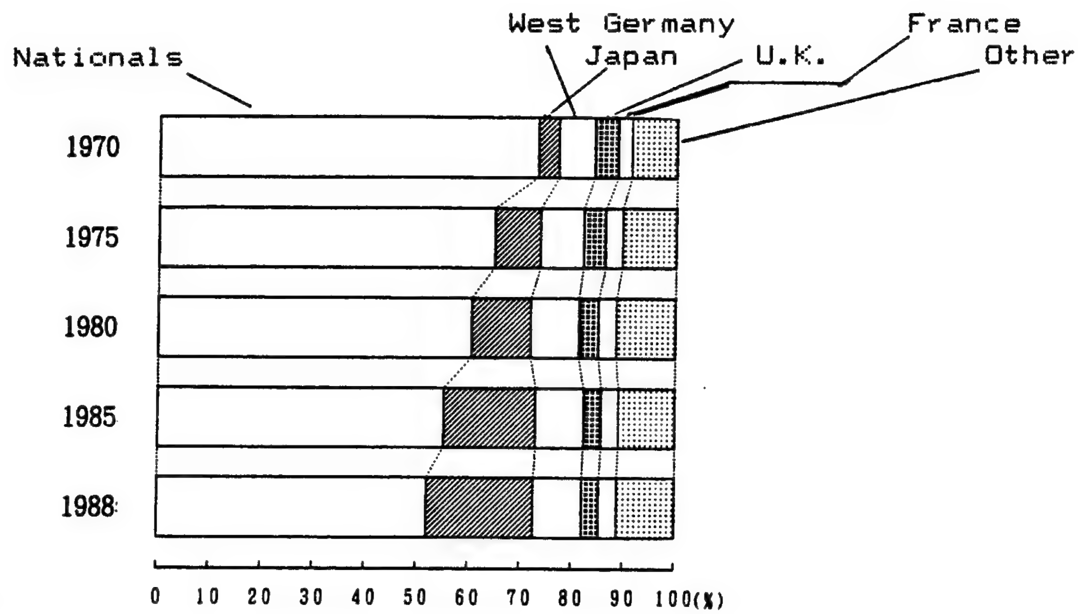
> Promoting joint international projects in space, high energy physics, the environment, etc.
>
> Strengthening the protection of intellectual proprietary rights; eliminating unfair competition limitations

The increase in the foreigners holding U.S. patent rights is something that hints at the next era. As shown in Figure 2-2-8,

already nearly 50% of the rights to U.S. patents are held by foreigners. The U.S. has never experienced this kind of a situation up until now.

Of those foreigners holding rights to U.S. patents, the percentage that Japan accounts for has reached a level of about 20%. It suggests that the situation has come to the point where the U.S. cannot ignore its mutually interdependent relationships.

Figure 2-2-8 Numbers of U.S. Patent Registrations By Nationality of Inventor (%)



Data: USPTO

2-2-1 Japan's Process

Primary factors in post-war Japan's realization of rapid technological growth were the active introduction of technology from Europe and the U.S., and vigorous R&D investments for the purpose of building upon the imported technology to create applied technology. This process of technological growth in post-war Japan can be thought of as divided into three periods: that of being generally dependent on foreign countries for technology imports (until the first half of the 1960's); the period when a conversion was seen in the industrial structure centered on the heavy and chemical industries (from the second half of the 1960's until the Oil Shocks); and the period of invigorated R&D in high-tech fields (after the Oil Shocks). One of the aims here is to take these chronological divisions and give a rough sketch of the technological growth processes that occurred.

1. The period of technology introduction (until the first half of the 1960's)

Post-war Japan's technology imports were resumed in 1950 as a result of the enactment of the "Foreign Capital Law"; in that year, there were suddenly 76 cases of technology imports. The occurrence of a special procurement boom due to the Korean War established a capital base in Japanese business, so afterwards technology imports were brisk.

At first, however, in accordance with the provisions of the "Foreign Capital Law," technology imports were subject to rigorous, case-by-case investigations concerning the payments involved, the tangible content of the technology, the effects that the imports would later have on the domestic economy, and so forth. With the revisions to the permissible standards in 1959, permission would be granted in principal as long as the technology import did not adversely affect the domestic economy. As a result, technology imports were much more brisk, reaching 588 cases in 1960.

A high percentage of technology imports during this period were chemical industrial products, general machinery, and electrical machinery; content-wise, there were many innovative technologies such as nylon fiber and the transistor.

It has been pointed out since long ago that the technology imports during this period were closely linked with investments in plants and equipment for the chemical and heavy industrial fields in particular, which had started to grow as new industrial fields. In the early 1960's especially, most technology imports were related to new investments in plants and equipment for the chemical and heavy industrial fields. This energetic introduction

of technology that was linked to the changes in the industrial structure then set the stage for independent R&D activities in the next period.

2. The period of heavy and chemical industries (from the second half of the 1960's until the Oil Shocks)

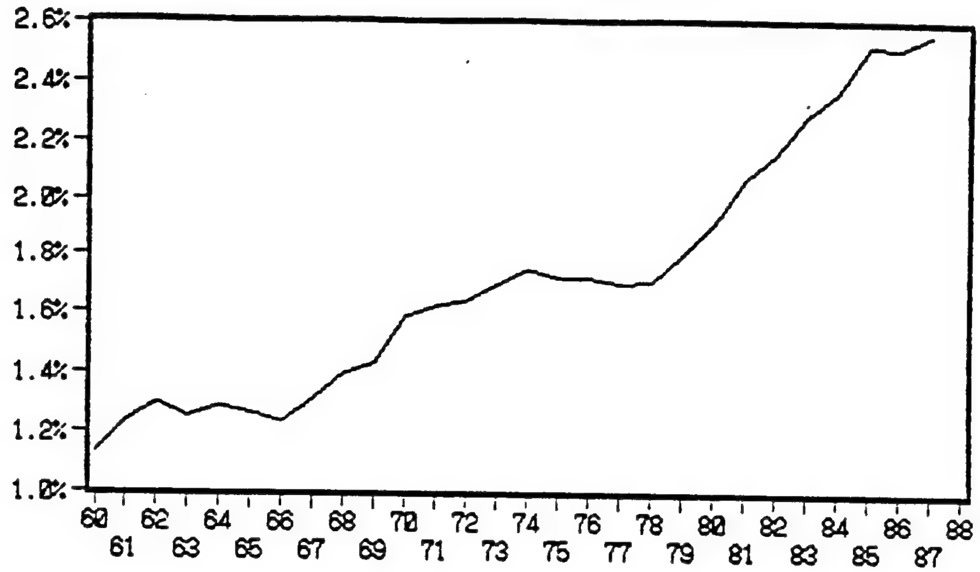
During this period the Japanese economy evolved into one based primarily on the heavy and chemical industries. Supported by an intermittently favorable business climate, corporate R&D investments expanded rapidly. From the early 1960's onward, businesses came to face the so-called "first research lab establishment boom," the objective of which was to achieve more efficiency in equipping the independent research base and in R&D functions (Note 4). As a result, the level of R&D expenditures as a percentage of GNP rose to more than 1.5%, as shown in Figure 2-2-9.

On the other hand, although technology imports were completely liberalized in 1968, the degree of dependence on technology imports began to relatively decline, as shown in Figure 2-2-10. This trend points to the fact that during the first half of the 1960's the level of Japan's technology had nearly "caught up" with European and U.S. levels. There is already valid research pertaining to this "catching up" period (Note 5).

At this time the percentage of Japan's patents that were owned by foreigners also decreased significantly. As can be seen in Figure 2-2-11, from 1955 to 1965 the percentage of patents owned by non-Japanese remained at a level of about 35%, nearly the same as that of the 1920's, but after 1965 it started to decrease.

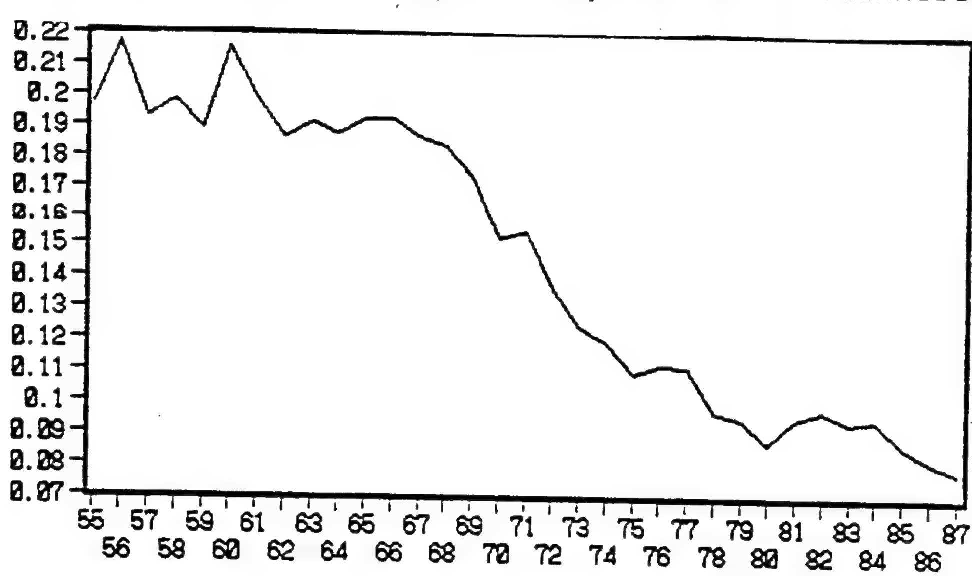
In addition to R&D in heavy and chemical industrial fields, large-scale R&D projects in the fields of space and nuclear energy commenced during this period. Businesses participated in these large-scale projects under the leadership of the government. Because of the spillover of R&D results from these projects, the same kind of characteristic as that of the U.S. government's traditional technology policies is seen. However, that scale is much less than that of the U.S. As shown in Figure 2-2-12, the percentage of Japan's research expenditures that were defrayed by national and regional public groups shifted over levels between 20% and 30% over the long term. Also, although the degree of contribution to that growth rate rose about 10% from 1965 through 1975, it has been significantly less than the degree of contribution from the private-sector (Figure 2-2-13).

Figure 2-2-9 Changes in Japanese Research Expenditures Measured as Percentages of GNP



Data: "Annual Report on the National Economy" Economic Planning Agency
"Investigative Report of Scientific and Technological Research" Management and Coordination Agency

Figure 2-2-10 Changes in Japan's Dependence on Technology Imports

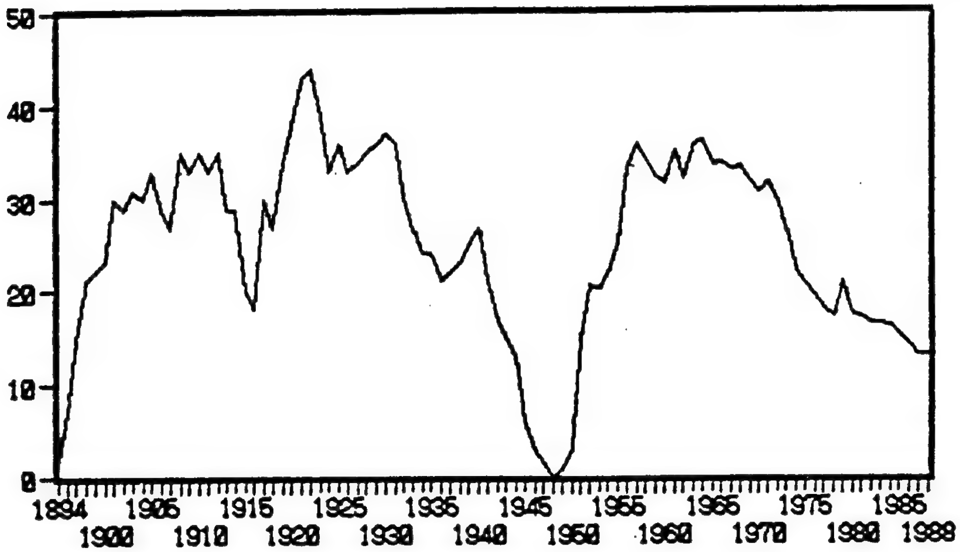


* Dependence on technology imports = Volume of technology imports / (Corporate R&D costs + Volume of technology imports)

Data: International balance of payments statistics, Bank of Japan

Figure 2-2-11 Percentage of Japan's Patents Registered By Foreigners

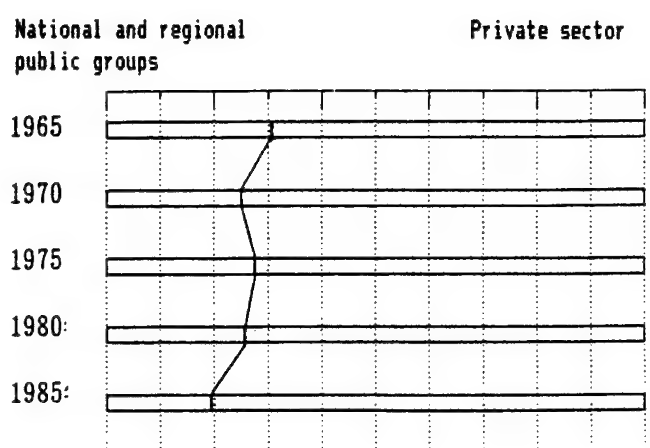
Unit: %



$$\text{Percentage of Patents Registered By Foreigners} = \frac{\text{Number of Patents Registered By Foreigners}}{\text{Total Number of Registrations}} \times 100$$

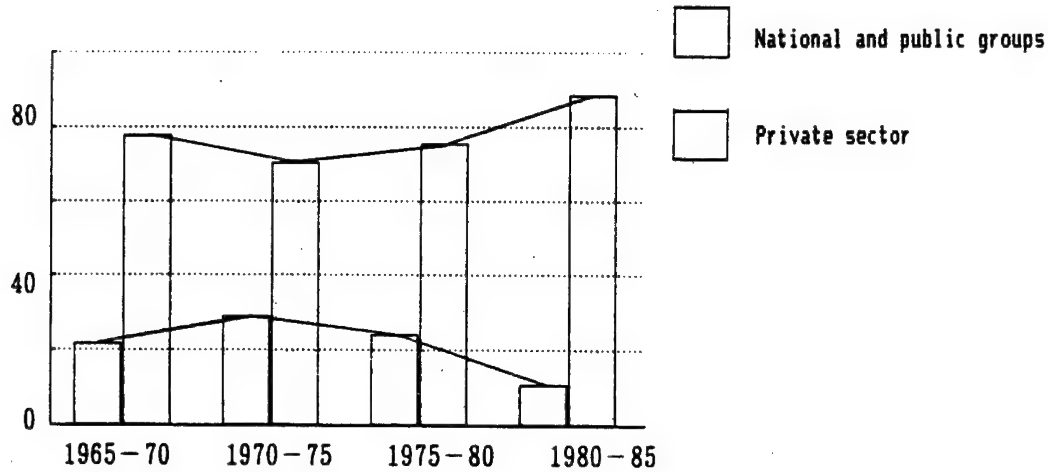
Data: Annual Report of the Patent Office,
Patent Office's Roundtable Discussion on Technology

Figure 2-2-12 Component Ratios of Japan's Research Expenditures By Source of Defrayment (%)



Data: "Survey of S&T Research" Patent Office

Figure 2-2-13 Degree of Contributions Towards the Rate of Increase of Japan's R&D Expenditures, By Source of Defrayment (%)



Note: Data from "Survey of S&T Research" was calculated using the formula below. If R is the total amount of R&D expenditures, and R1 and R2 are R&D expenditures from each source, then the rate of increase from a previous period, t-1, to the present period is:

$$\frac{R_t - R_{t-1}}{R_{t-1}} = \frac{R1_t - R1_{t-1}}{R_{t-1}} + \frac{R2_t - R2_{t-1}}{R_{t-1}}$$

3. High-tech period (after the first Oil Shock)

The rise in energy prices after the Oil Shocks gave momentum to the rapid shift in Japan's industrial structure away from mainly heavy and chemical industries to fabrication and assembly industries. This change also affected the by-industry structure of outlays for R&D expenditures. During the first half of the 1970's, the growth rate of the transportation machinery (i.e., automobiles, aircraft, etc.) industry's R&D expenditures was high. In the second half of the 1970's, though, there was a sudden increase in that growth rate for the communications, electronics, and electrical measurement equipment industries.

On the other hand, Japanese technology exports to developing countries increased rapidly at this time, and Japan became involved in competitive relationships in R&D activities with the developed countries of Europe and the U.S. By the time the 1980's arrived, Japan entered into the so-called "second research lab establishment boom," the objective of which was to promote the internationalization of business, the development of different industries [working as single large enterprise], and creative R&D

activities; and private sector leadership in R&D activities became more markedly demonstrated.

Notes 4. Refer to the Government Industrial Research Institute's "Trends and Topics in Industrial Technology" 1988.

5. Jorgenson and Nishizimu "U.S. and Japanese Economic Growth, 1952-74: An International Comparison" 1978

2-2-3 Korea's Course

When the Korean peninsula was divided into south and north after the Second World War, industrial technology was unevenly distributed in the northern region of Korea. Also, the south lost most of its few engineers as a result of the Korean War that broke out in 1950. Korea was placed under the worst possible conditions for acquiring technological growth. Nevertheless, the First Five-Year Economic Development Plan of 1962 marked a great turning point in the evolution of Korea's economy, and modernization and industrialization began to rapidly move forward. Here we will rely on the research of Boku and Moritani (Note 6) to give a brief account of the economic and technological growth in Korea since the 1960's and will look at importance of technology imports in that economic development process.

The basis of Korea's technology policies during the 1960's was to rely on developed countries for technology, production facilities, and plant engineering, and then to make use of that in efficiently advancing product exports and import substitutes. Based on those policies, Korea processed imported raw materials and intermediate products and then exported the resulting products; also, by applying those towards domestic demand for the purpose of import substitutes, rapid growth in the production and export of labor-intensive light industrial products became possible.

On the other hand, in order to achieve growth in advanced technology, while Korea expanded its plant engineering capabilities and its metal-processing machinery industries, there was a gradual conversion from production equipment imports to technology imports. In 1961, provisions of the "Foreign Capital Encouragement Law" relaxed the restrictions on foreign capital, and, with the normalization of diplomatic relations with Japan during the same year, Korea's technology imports suddenly increased (Note 7).

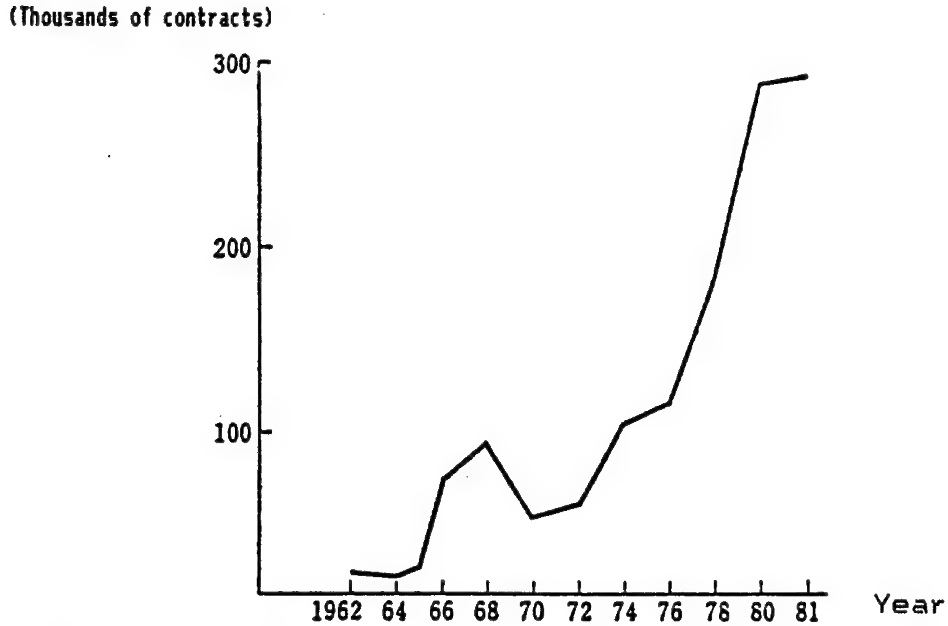
Furthermore, a target was set for the light-industrial sector to become at least 50% self-sufficient in production technology; on the other hand, advanced technology needed for the heavy and chemical industries would continue to be imported. This kind of plan aimed at 100% technological self-sufficiency in the light-industrial sector in the early 1970's; it promoted technology exports in the heavy and chemical industries as well, except for some advanced technologies; and it called for having the capabilities for selling patents and technological know-how.

Actually, because there was an apparent limit in the 1970's to the industrialization and growth in exports by light industries alone, government policies emphasized the heavy and chemical industries. As a result, the relative weight of heavy and chemical industrial production increased from 32% in 1972 to 51% in 1981. However, as far as technological growth is concerned, a similar rate of progress was not made. Through the 1960's, when labor-intensive industries were becoming export-oriented, not only was the required level of technology low, but because virtually all technology was brought in to be incorporated into production facilities, it was not necessary to stress technology acquisition or domestically coping with improvements upon or development of technology. Nevertheless, even when the structural transition to high-class technology became unavoidable, the transition was still not dealt with adequately, and only excessive investments were made in heavy industry. Consequently, the internalization of technological know-how was extremely late.

Industrial policies,through preferential financing and loans, afforded businesses conditions that enabled the easy pursuit of profits. As a result, it brought about a business environment that did not place any special importance on the development of technology. Furthermore, because monopolisitic or oligopolisitic systems were encouraged in an attempt to rationalize the scale of production, the building of a free-competition system based on technological superiority was hindered. To make matters worse, businesses had to neglect technology development, which is a long-term investment, because of the high inflation rate and high interest.

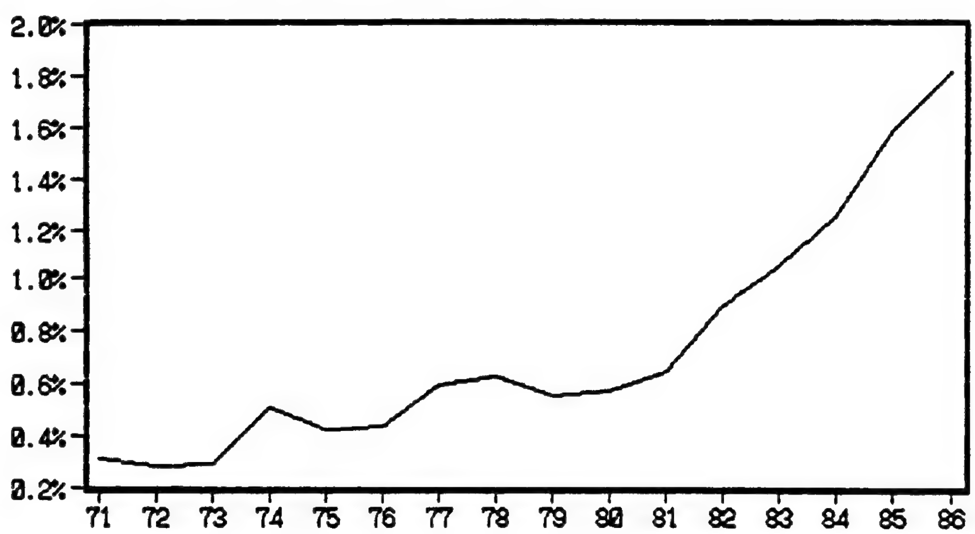
In such an environment where the desire to independently develop technology was suppressed, advanced technology continued to be imported from overseas. In the previously mentioned "Foreign Capital Encouragement Law," the objective of which was to control the increase of payments to foreign countries, the 1969 and 1973 revisions added strict regulatory conditions for technology imports, but since 1978 liberalization policies to relax regulations were implemented. First, the scope of automatic authorizations was successively expanded; when the "Foreign Capital Encouragement Law" was revised in 1984, the authorization

Figure 2-2-14 Numbers of Technology Import Contracts in Korea



Data: Korean Developmental Research Institute "S&T Policy Data"

Figure 2-2-15 Changes in Korea's Research Expenditures As Percentages of GNP



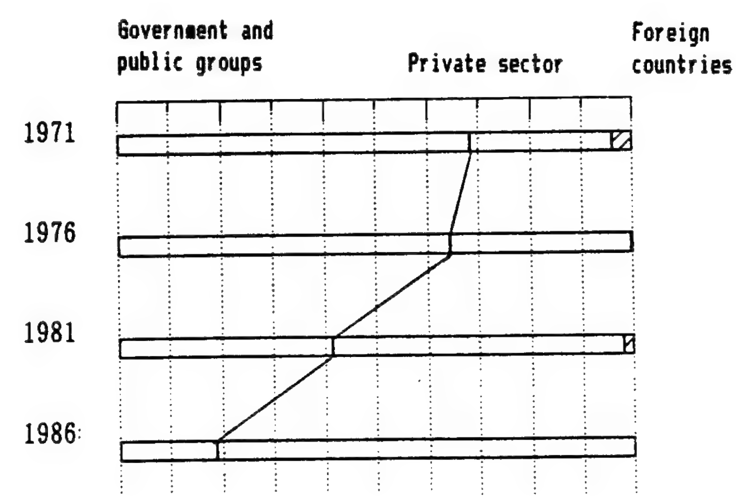
Data: Korean S&T Yearbook 1987

system in use up until then was converted into a notification system (Note 8). As can be seen in Figure 2-2-14, the number of technology imports increased by leaps and bounds as a result of these liberalization policies. The setting up of a patent system after 1970 also accelerated that increase.

With the liberalization of technology imports as a turning point, Korea's R&D activities have also become more vigorous. As shown in Figure 2-2-15, the percentage of GNP spent on R&D has been rising rapidly since the 1980's.

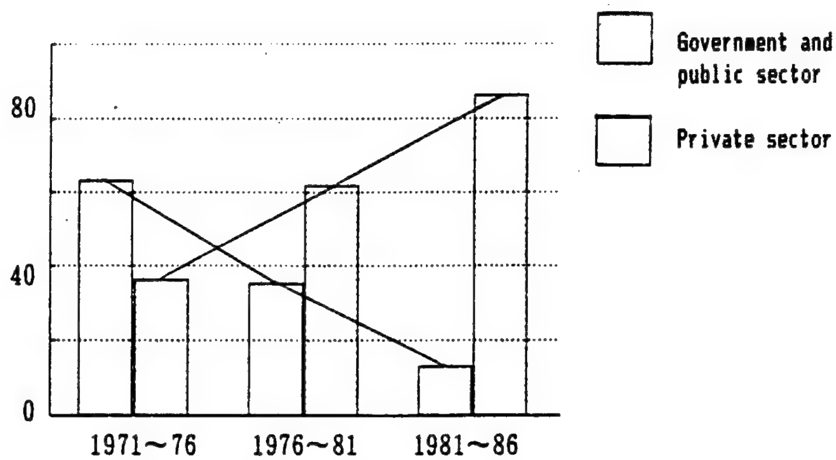
Much of this increase in R&D expenditures is born by the private sector. During the 1970's, the percentage of R&D expenditures defrayed by the private sector was at a level between 30-35%, but in 1981 it rose to about 60%, and in 1986 it reached a level of more than 80% (Figure 2-2-16). Also, the percentages of contributions to that increase by the government and public sector and by the private sector underwent a reversal from the 1970's through the 1980's (Figure 2-2-17). This increase in the R&D strength of the private sector is starting to bring about a change in the situation where more than 80% of Korea's patent applications are from foreign countries; the percentage of Korean applicants is starting to increase, as shown in Figure 2-2-18.

Figure 2-2-16 Component Ratios of Korea's Research Expenditures By Source of Defrayment (%)



Data: "Korean S&T Yearbook" 1987

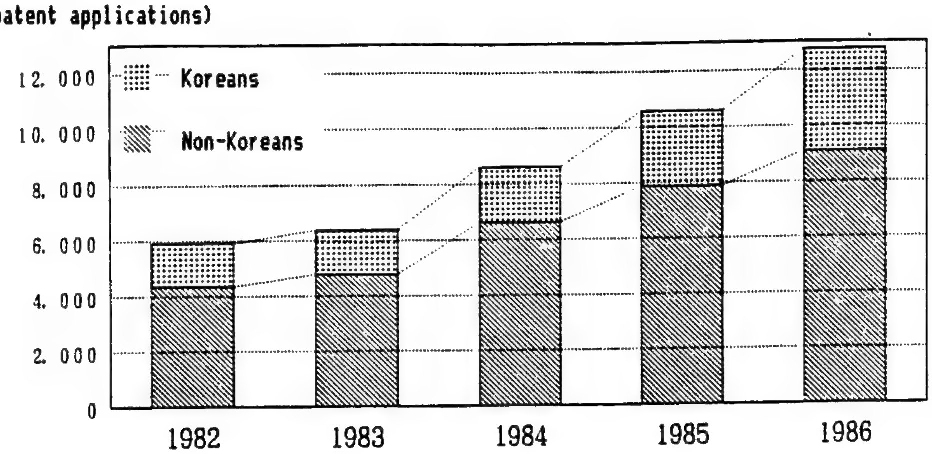
Figure 2-2-17 Degree of Contributions Towards the Rate of Increase of Japan's R&D Expenditures, By Source of Defrayment (%)



Note: The following formula was used on data taken from the "Korean S&T Yearbook." If R is the total amount of R&D expenditures, and R1 and R2 are R&D expenditures from each source, then the rate of increase from a previous period, t-1, to the present period is:

$$\frac{R_t - R_{t-1}}{R_{t-1}} = \frac{R1_t - R1_{t-1}}{R_{t-1}} + \frac{R2_t - R2_{t-1}}{R_{t-1}}$$

Figure 2-2-18 Comparison of Korean and Foreign Applicants for Korean Patents



Data: "Korean S&T Yearbook" 1987

From the above we can see that the activation of R&D activities in Korea during the 1980's unfolded under the leadership of the private sector and that it serves to supplement imported technology.

In recent years it is said that in Korea imported technology is undergoing model-improvements and other such changes and is gradually taking root. From now on, however, in order to establish serious horizontal international specialization systems with developed countries, Korea will have to emerge from its predisposition towards depending on imported technology. Regarded as the foundation of Korea's S&T policies, the "Long-Term Development Plan for Science and Technology Oriented Towards the 2000's (1987-2001)" has as its objective Korea's actual entrance by the year 2000 into the technologically advanced countries; it holds up all policies whose purpose is to actively promote independent R&D.

Reference: Korean Technology Imports By Trading Partner (1962-86)

	U.S.	Japan	W. Germany	France	Other	Total
Number of cases	981	2,199	215	128	532	4,055
Amount of payments (millions of dollars)	791.6	527.2	71.2	50.6	309.3	1,749.8

Notes 6. Uhiro Boku's and Masanori Moritani's "Economics of Technology Assimilation" 1982.

7. Looking at the countries from which Korea imported technology between 1962 and 1986, Japan accounted for 54.2%, the largest share. In terms of the amount of royalty payments for the technology imports, however, the U.S. had the largest share, 45.2%. That is, the per-unit price of technology imports from Japan is relatively low. Japan stands out as a major trading partner of Korea: in all major areas--general machinery, electrical machinery, chemicals, etc.--more than 50% of Korea's imports are from Japan.

8. For information about the vicissitudes of policies on technology imports, see "The Roles of Technology Imports and Government" by Kim and Li (NIRA Policy Research 1988, Vol 1).

9. For an overview of Korean S&T policies, see Kim's "S&T Policies of Korea" (Future Engineering Research Institute, "IFTECH NEWS" January 1989).

2-2-4 Thailand At Present

The ASEAN country Thailand follows the U.S., Japan, Korea, and NIES countries such as Taiwan.

As seen in Chapter 1, the basic structure of Thailand's technological state of affairs is ruled by technology imports and investments from overseas.

Although Thailand has been implementing five-year-long national socio-economic development plans since 1962, the importance of S&T policies has only been recognized since 1977, when the fourth plan was begun. The significance of S&T was made clear in the fifth and sixth plans, the first time that the utilization and development of S&T were formally mentioned as goals.

Drawing up policies related to the arts and sciences started in 1949; in those accomplishments various organizations were successful, and several were established so that they would become successful. Although this indicates that Thailand's national development is heavily dependent on S&T, emphasis was placed on education in the S&T policies of the past, as seen in the broad curriculum reforms of 1970.

As mentioned before, a part of the economic reconstruction of the fifth plan (1982-1986) was the first time that S&T policies came to be regarded as important.

These plans emphasize the importance, with respect to national development goals, of strengthening S&T research organizations, improving the quality of research personnel, and promoting R&D activities. In concrete terms, the following kinds of policies were drawn up.

1. Government policy guidelines
   - Expanding useful technology; the careful selection, improvement, and domestic application of imported technology; development of independent technology for improving productivity and for effective utilization of resources.
   - Strengthening and improving the S&T base by centralizing research personnel, research organizations, technology transfer centers, S&T data centers, etc.
   - Promoting the activation of private- and government-run enterprises by the effective and practical utilization of technology for improving productivity; disseminating S&T and providing instruction to the people.
   - Strengthening international S&T cooperation through information exchange, technology transfer, etc.

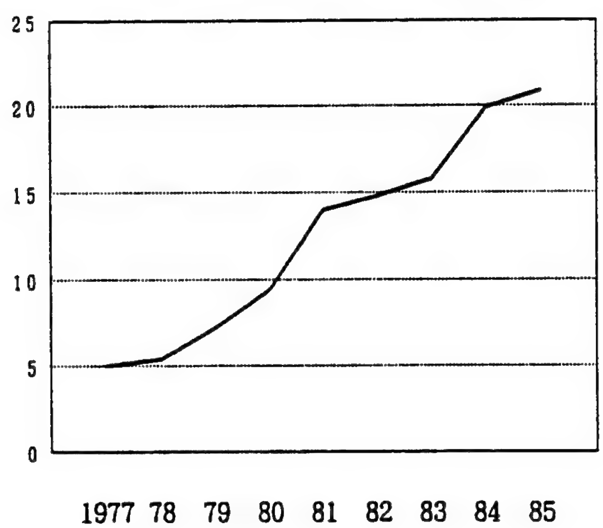
2. Plans and guides

- Gathering the basic data needed for technology development
- Promoting technology imports
- Improving the efficiency of domestic S&T research
- Strengthening resources and making them more fluid (particularly research personnel)
- Reforming product standards and quality control (including international standards and testing methods)
- Developing domestic engineering consultant services
- Raising the standards of S&T information systems
- Promoting technology transfer within Thailand
- Making the process of drawing up science policies more advanced
- Strengthening international S&T cooperation
- Disseminating S&T and providing instruction to the people.

The main objectives of the sixth plan (1987-1991) are solving the socio-economic problem points that previous plans did not deal with adequately, and further promotion of national development.

Since 1980 Thailand's technology imports have sudden expanded (Figure 2-2-19), reaching a level of 2.1 billion bahts in 1985.

Figure 2-2-19 Thailand's Technology Imports (in 100's of Millions of Bahts)

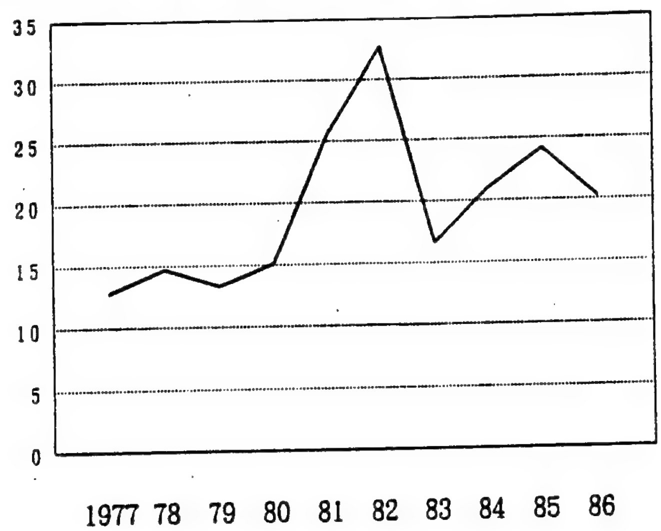


Data: Thailand Science & Technology Indicators 1987
U. N. Technology for Development

The Thai government has been desperately promoting policies that attempt to make technology imports more positive, to absorb this technology and then form the country's own technological base, and to raise the level of R&D strength.

Nevertheless, Thailand's policy-type coping is not necessarily without problems; neither is it systematic. As can be seen in Figure 2-2-20, the great deviation in the S&T-related government budgets perhaps symbolizes the groping that is going on at the policy-making level of the Thai government.

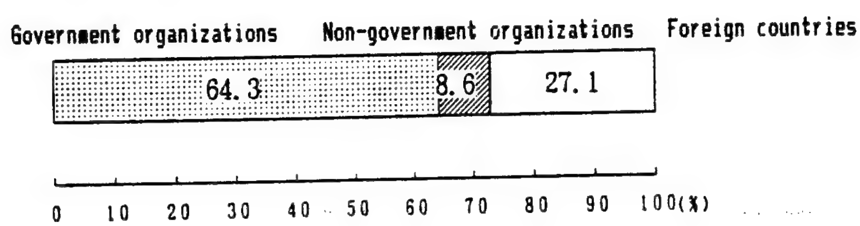
Figure 2-2-20 Thailand's S&T-Related National Budgets (in 100's of Millions of Bahts)



Data: Thailand Science & Technology Indicators 1987

Because Thai R&D is heavily dependent upon government leadership, this "groping" will become an even larger problem. As shown in Figures 2-2-21 and 2-2-22, government organizations actually defrayed more than 64.3% of the 1986 expenditures for R&D, of which government organizations' research bodies used 91.3%.

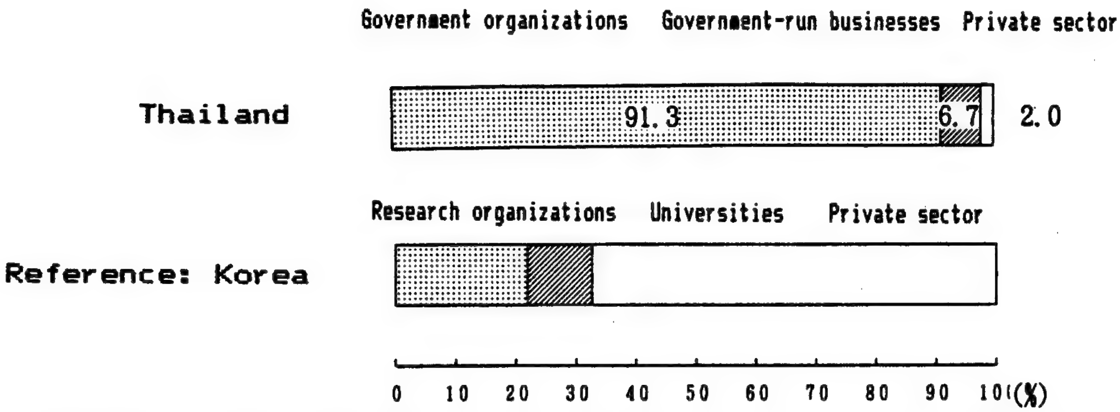
Fig. 2-2-21 Thai R&D Expenditures By Source of Defrayment (1986)



* The total amount was 2.14500 billion bahts

Data: Thailand Science & Technology Indicators 1987

Figure 2-2-22 Thailand's R&D Expenditures By Research Body (1986)



* Thailand's total amount of R&D expenditures was 2.14500 billion bahts; Korea's was 1.5232 trillion won

Data: "Korean S&T Yearbook" 1987

Thailand Science & Technology Indicators 1987

There is quite a contrast between Thailand and Korea in the comparison of R&D expenditures by research body.

In Thailand's case, a structure is seen that resembles the dilemna where, even though policy-type leadership by the government facilitates growth in the private sector, that contribution to private-sector R&D is still only a little bit.

Historically, whenever a nation fosters its industries and tries to form a scientific and technological base, powerful policy-type initiatives always come into play. Such was the case with Japan and Korea. Thailand's situation certainly symbolizes that fact.

2-3 Structural Changes in International Relationships

2-3-1 Important Factors in Cooperative Relationships

Here we will return to the international relationship model of R&D activities that we established in the opening section of this chapter. In light of the concrete growth processes discussed in the previous section, we will take into consideration the present-day international situation.

First of all, it is clear that, from the end of World War II until the first half of the 1980's, international politico-economic relationships, in which the U.S. was the leading country, were such that technology transfer was the center around which virtually stable cooperative relationships were maintained in scientific and technological R&D activities. The four most important factors in being able to maintain such long-term cooperative relationships are as follows: 1) In the R&D activities of the U.S., as the leading country, public-sector-based support through the NSF, NIH, DOC, and other such organizations played a great role; basic research results that had the nature of public property were produced; and the resulting scientific and technical knowledge accelerated the activation of worldwide R&D. 2) The evolution towards a global market that was due to the tremendous vitality of the leading country's private sector made international technology transfer smoother. 3) In the R&D activities of a country such as Japan, which is a late starter in its relationship with the U.S., positive developments could be made out of the technology imports from the leading country because the group that demonstrated its leadership abilities was the private enterprises that made their fortune on applications and development. 4) As a result of government initiatives, countries starting much later than the U.S. and Japan--Korea, Thailand--are making their technology imports from the leading country and from late-starting Japan positive, and are putting their energy into the formation of a private-sector R&D base that will support industrial growth.

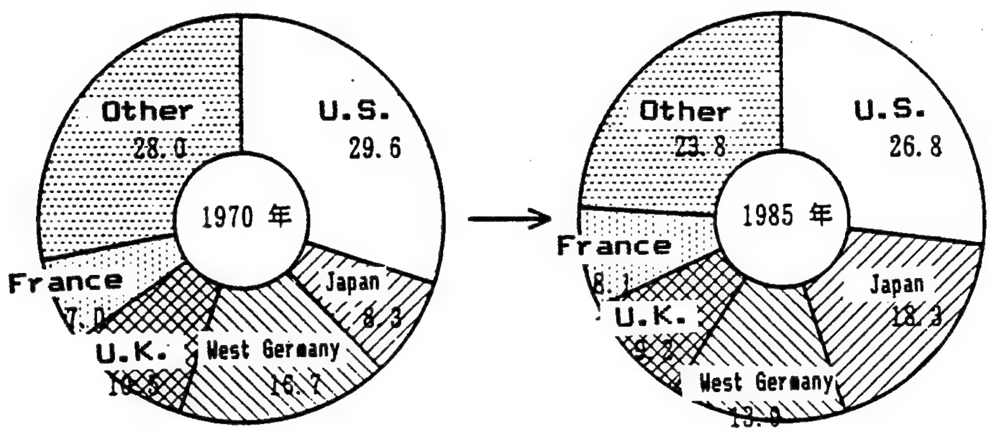
2-3-2 The Manifestation of Competition and the Future

The international relationship model of the opening section establishes the competitive and cooperative relationships as important functions. Now, in order to think about the current [state] and future of international relationships, although we have already seen it in Chapter 1, we will take another look at the trade trends of high-level-R&D-intensive industries for different countries.

As shown in Figure 2-3-1, in 1970 the U.S. share of exports from high-level-R&D-intensive industries amounted to 30%; Japan's was

only 8%. However, 15 years later in 1985, Japan's share of those exports rose 10%; conversely, the U.S. share lost 3 percentage points. Looking at the trade balances shown in Figure 2-3-2, there was a significant decline in the margin of the U.S. trade surplus from 1980 through 1985, while Japan's grew rapidly after 1975; by 1985 Japan's trade surplus was much greater than that of the U.S.

Figure 2-3-1 Export Shares in High-Level-R&D-Intensive Industries By Country (%)



Data: UNITED NATIONS "Trade and Development Report, 1987"

From this data the relative decline in the U.S.'s position as the leading country is evident. And, this drop in the U.S.'s position can be seen as leading to the instability of the previous kind of post-World War II cooperative relationship that revolved around the flow and transfer of scientific knowledge and technology centered on the powerful nation, the U.S. It can be thought of as becoming an important factor in the manifestation of competitive relationships. More than anything else, the manifestation of trade disputes and intellectual property rights problems symbolizes this instability.

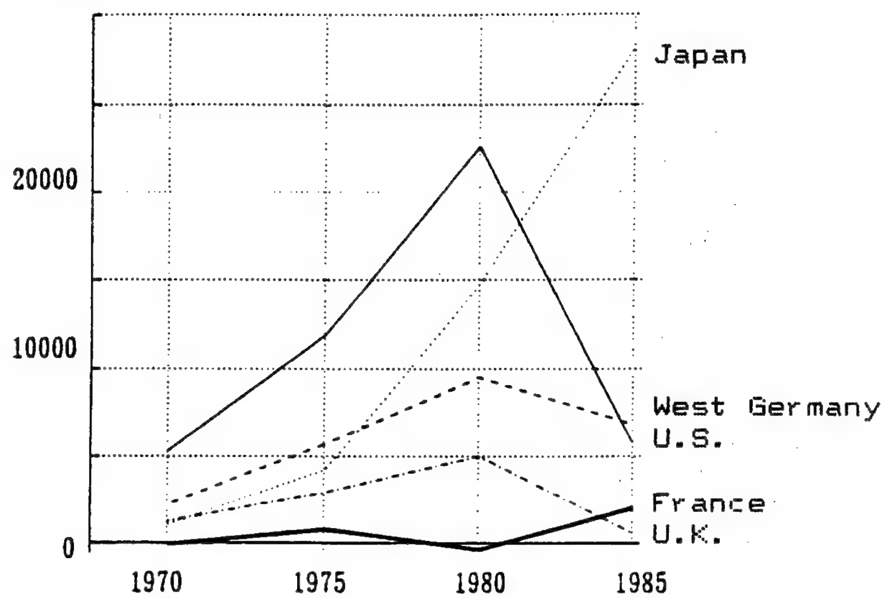
Coping with these kinds of structural changes in the international relationships occurring in R&D activities, and then maintaining a balance between the cooperative and competitive relationship axes are probably extremely difficult policy-making problems for any country. What can also be taken into consideration from the model established in the opening section is that, by promoting joint research--and other such activities that are not shackled by a single country's policy framework--it

yields new research results that have the nature of public property, and the smooth international transfer of those results may become a solution method in coping with structural changes. For example, various attempts towards inter-government-level R&D cooperation are already being made in Japan as well (see Attached Lists 2 and 3); we are heading towards the formation of a new-age framework for competition and cooperation.

With the 1992 EC unification near at hand, Europe is also about to go through some great changes. At another opportunity we would like to conduct a detailed investigation of international relationships that also include Europe.

Figure 2-3-2 Trade Balances in High-Level-R&D-Intensive Industries, By Country

(Millions of Dollars)



Data: UNITED NATIONS "Trade and Development Report, 1987 "

Chapter 3. Internationalization of R&D Activities in Business

With increasingly higher incentives for overseas investments owing to both the advancement of Japan's corporate R&D and the changes in the external economic environment, it has become apparent that there are many businesses among the large manufacturing companies that are striving for active overseas development, with respect to not only production strongpoints but R&D strongpoints as well. In this chapter, we will give an overview of overseas R&D activities in terms of the new modes of those activities, basing this on existing research statistics and the aggregate statistical results of the "International R&D Trends Questionnaire Survey" that was carried out last year.

3-1 Locations of Overseas Research Labs and State of Activities

Table 3-1 shows the state of R&D activities in the overseas subsidiaries of Japanese businesses based on data taken from MITI's "Basic Investigation of Overseas Business Activities" (Note 1).

According to this investigation, the businesses surveyed had a total of 119 overseas research labs in FY 1986; researchers numbered 3,153; R&D expenditures were about 57.7 billion yen. R&D expenditures amounted to 0.1% of the overseas subsidiaries' sales. This percentage is much lower than that for the main offices, whose R&D expenditures were 1.3% of their sales volume.

For different types of industries, obvious deviations in the level of overseas R&D activities can be seen. That is, the scale of R&D expenditures of those industries that are regarded back at home as R&D-intensive--chemicals, general machinery, electrical machinery, transportation machinery--is greater than that of other types of industries. The ratio of R&D expenditures to sales volume for the former is also getting higher. We can say that these kinds of industries are evolving as R&D-intensive industries abroad as well.

In a trial calculation for these four industries, the chemical industry had 22.6 researchers per lab; general machinery, 26.4; electrical machinery, 38.4; and transportation machinery, 28.7. Except for the slightly larger number of researchers in electrical machinery labs, there were no outstanding differences in the size of research labs for these types of industries. With respect to R&D expenditures per researcher, however, the chemical industry spent 13.3 million yen per researcher; general machinery, 16.0 million yen; electrical machinery, 18.6 million yen. The transportation machinery industry's R&D expenditures were noticeably high: 76.5 million yen per researcher.

Even among the industries that are generically referred to as R&D-intensive, we can see that there are broad differences in the patterns of R&D resource investments.

Table 3-1 State of R&D Activities in Overseas Subsidiaries of Japanese Businesses

	Number of labs	Number of researchers	R&D expenditures (million yen)	R&D expenditures/ sales (%)
All industries	119	3, 153	57, 653	0. 1
Manufacturing industries	88	2, 463	43, 553	0. 4
Food products	2	6	6	-
Textiles	4	24	61	-
Wood, paper, pulp	2	20	65	0. 1
Chemicals	18	406	5, 394	0. 7
Iron and steel	2	396	501	0. 1
Nonferrous metals	2	12	98	0. 1
General machinery	11	290	4, 654	0. 6
Electrical machinery	20	767	14, 283	0. 4
Transportation machinery	6	172	13, 155	0. 8
Precision machinery	5	49	377	0. 1
Petroleum & coal products	0	0	0	0. 0
Other manufacturing industries	16	321	4, 959	0. 5

Note 1. These investigations, the objective of which is to grasp the actual state of overseas business activities of Japanese enterprises, were carried out every three years since 1981. Results of the third investigation, a survey for FY 1986, are the newest data that is currently available. The number of overseas corporations that responded to the third survey is reported to be 4,579 companies. In the survey data from the year before, data of the second investigation was analyzed, but because the response conditions vary for each investigation, it is thought that in a chronological comparison the data from the year before would not fit in.

Data: MITI "Third Basic Investigation of Overseas Business Activities"

3-2 Comparison with Foreign Affiliates

Next we will compare the R&D activities of overseas Japanese subsidiaries to those of companies in Japan with foreign capital affiliations.

Taken from the data in MITI's "Trends in Foreign Affiliates" (Note 2), Table 3-2 is a collection of indicators, similar to those in Table 3-1, pertaining to R&D activities in 1988.

According to this data, there are 144 research labs of foreign affiliates in Japan with about 7,800 researchers; R&D expenditures are about 100.3 billion yen. The ratio of R&D expenditures to sales is 0.9%, indicating a higher level of R&D activity than that of overseas Japanese subsidiaries.

The 54.4-researchers-per-lab figure seen in the industry totals is much greater than the industry-total data for overseas Japanese subsidiaries (26.5 researchers per lab). However, the industry-total figure for foreign affiliates' per-researcher R&D expenditures is 12.8 million yen, slightly lower than the 18.3 million yen per researcher for overseas Japanese subsidiaries.

If we pay attention to the aggregate values of R&D-expenditures-to-sales ratios according to the types of industries, the point that R&D-intensive industries--chemicals, pharmaceuticals, electrical machinery--show high percentages leads us to believe that these have the same characteristics as Japanese companies in R&D-intensive fields. However, for foreign affiliates, it is noted that the ceramics and stone, metal products, and precision machinery industries also show high percentages. On the other hand, although the transportation machinery and general machinery industries show relatively high R&D-expenditures-to-sales ratios, those levels are slightly below average.

The patterns of investments in R&D resources vary widely according to the type of industry. Looking at pharmaceuticals and electrical machinery, the types of industries with the highest R&D-expenditures-to-sales ratios, there are 56.2 researchers for one pharmaceuticals lab and 23.6 million yen spent on R&D for each researcher, whereas electrical machinery labs have a surprisingly larger number of researchers, 251.3 researchers per lab, but they spend only 7.2 million yen per researcher on R&D.

Although Japan has a superior position in machinery-related industries when compared with other developed countries, it has not acquired as much superiority in chemicals and pharmaceuticals. So, the data above suggests that the incentives for foreign affiliates to promote R&D activities in Japan vary widely depending on the type of industry.

Table 3-2 State of R&D Activities at Foreign Affiliates in Japan

	Number of labs	Number of researchers	R&D expenditures (million yen)	R&D expenditures/ sales (%)
All industries	144	7,836	100,294	0.9
Manufacturing industries	112	7,164	90,678	1.3
Food products	4	73	1,385	0.7
Textiles	0	0	0	0.0
Lumber and wood products	0	0	0	0.0
Pulp and paper	1	11	243	0.3
Publishing and printing	0	0	1	0.0
Chemicals	47	1,377	16,712	1.5
Pharmaceuticals	26	1,462	34,467	4.9
Petroleum	6	648	4,350	0.2
Rubber products	3	21	27	0.0
Leather products	0	0	0	0.0
Ceramics and stone	2	37	783	1.6
Iron and steel	0	0	0	0.0
Nonferrous metals	3	203	364	0.1
Metal products	1	30	374	2.4
General machinery	2	34	4,116	0.8
Electrical machinery	12	3,016	21,852	3.2
Transportation machinery	2	75	1,921	0.7
Precision machinery	3	177	3,015	1.7
Weapons	0	0	0	0.0
Other manufacturing industries	0	0	1,068	0.7

Note 2. These investigations have been carried out every year since 1967. Based on this survey data, the report for the previous fiscal year is a time-series study of R&D activities of foreign affiliates.

3. The pharmaceutical industry is classified under the chemical industry in the "Basic Investigation of Overseas Business Activities."

Data: MITI "Twenty-Third Trends of Foreign Affiliates"

3-3 State of Activities By Region

Next, we will look at the state of R&D activities in the overseas research labs of Japanese businesses according to the regions in which the labs are located.

From the trends in the locations of overseas research labs, as shown in Figure 3-1, we can point out the following points:

1) North America has the largest number of Japanese research labs (46), of which 21 are based on non-manufacturing industries, e.g., commerce, services, etc. Of the manufacturing-industry labs, those for general machinery (9 labs) and electrical machinery (7 labs) are comparatively numerous.
2) Asia has the next largest number (43 labs). The research lab sites in Asia center on the chemical (12 labs), electrical machinery (21 labs), and "other" manufacturing (13 labs) industries.
3) There are 17 Japanese research labs in Europe that are dispersed among different types of industries.
4) In both Oceania and Central and South America there are less than 10 labs. However, the research labs established in these regions are for the types of industries not seen in other regions, e.g., agriculture, forestry, and the fishing industry (Oceania); mining (Oceania and South America), etc.

From Figure 3-2, which shows R&D outlays in these labs by type of industry, we can point out the following regional differences:

1) R&D outlays in North America are about 28.4 billion yen, noticeably higher than those other regions. If the commerce and service industries are excluded, R&D-intensive industries account for a large share of R&D outlays: electrical machinery, 33.3%; transportation machinery, 18.9%; and general machinery, 12.7%.
2) R&D outlays are the next largest in Europe (about 16.6 billion yen), where those for the electrical machinery (44.6%), "other" manufacturing (27.8%), and the chemical (17.0%) industries are high.
3) R&D outlays in Oceania and Central and South America are each about 1.2 billion yen. The types of industries that account for relatively high distribution ratios in the by-type-of-industry shares are not found in other regions.

Figure 3-1 Overseas Research Labs of Japanese Businesses (FY 1986) (Unit: lab)

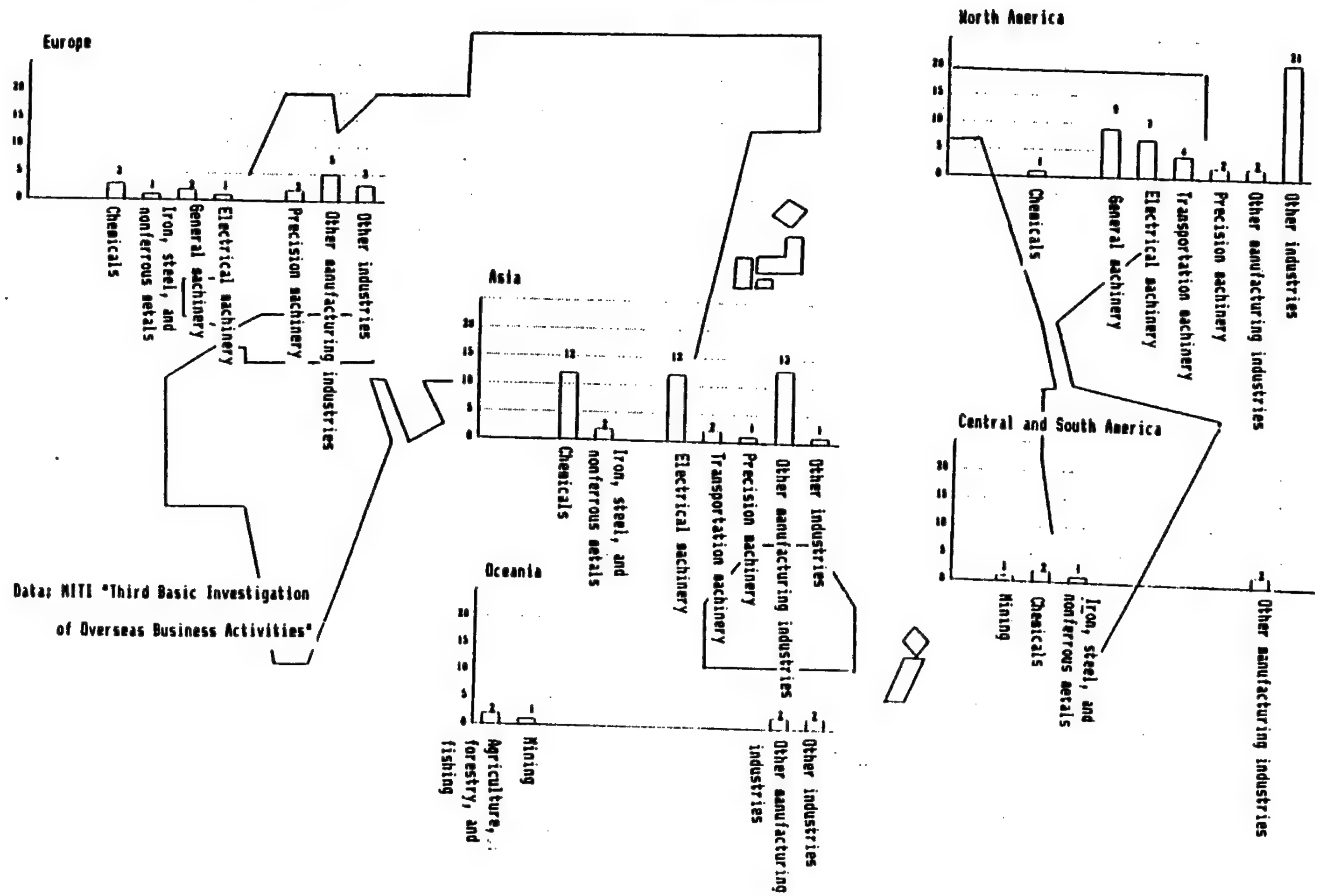
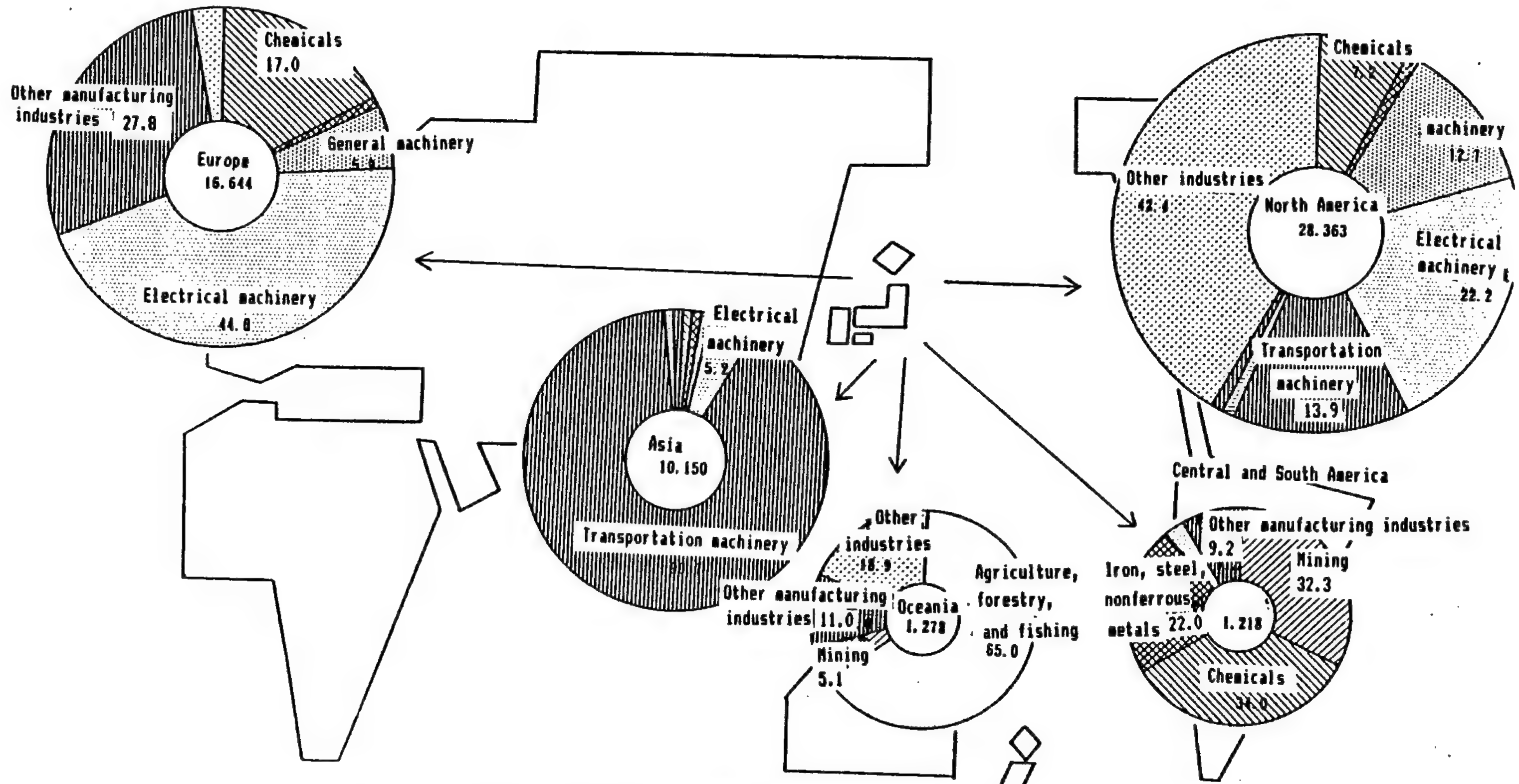


Figure 3-2 R&D Expenditures in Japan's Overseas Strongpoints
(FY 1986) (Unit: 1 million yen)



Data: MITI "Third Basic Investigation of Overseas Business Activities"

3-4 Important Factors in the Implementation of Overseas R&D

Next, we will outline the kinds of factors involved in Japanese businesses' implementation of overseas R&D activities.

First we will examine the relationship between overseas R&D activities and the degree of technological dependence on the region where those activities are carried out. Table 3-3, the data of which is taken from the "Basic Investigation of Overseas Business Activities," shows, as the degree of technological dependence on local businesses, the percentages of overseas subsidiaries whose technology is procured mainly from local businesses, by industry and by region.

Table 3-3 Degree of Overseas Subsidiaries' Technological Dependence on Local Businesses (%)

	Total	North America	Central & S. America	Europe	Asia	Oceania
All industries	6.1	18.4	6.5	11.7	1.1	16.7
Manufacturing industries	4.6	16.2	7.4	6.3	0.9	14.3
Food products	43.8	85.7	X	X	0.0	X
Textiles	1.6	X	0.0	X	2.1	X
Wood, paper, pulp	23.5	40.0	X	X	0.0	50.0
Chemicals	7.7	18.8	33.3	12.5	0.0	X
Iron and steel	8.6	11.1	X	X	4.5	X
Nonferrous metals	16.7	X	X	X	0.0	X
General machinery	5.6	12.5	0.0	33.3	0.0	X
Electrical machinery	1.0	8.3	0.0	0.0	0.0	0.0
Transportation machinery	1.1	0.0	8.3	0.0	0.0	0.0
Precision machinery	0.0	0.0	X	0.0	0.0	X
Petroleum & coal products	0.0	X	X	X	X	X
Other manufacturing industries	3.1	5.3	0.0	9.1	2.5	0.0

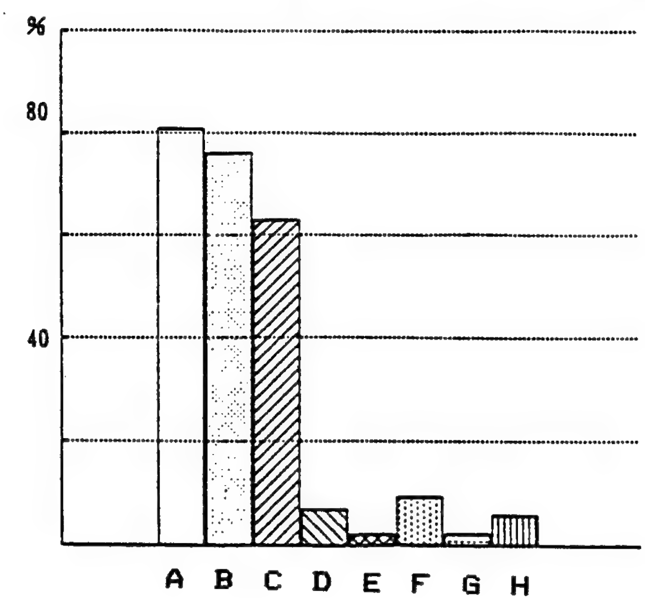
* These the percentages of companies who replied that their technology is mainly procured from local businesses.

* "X" indicates that there were less than three samples for that kind of industry in that region.

Data: MITI "Third Basic Investigation of Overseas Business Activities"

According to this table, North America is the region where, throughout all industries, there is the highest degree of technological dependence on local businesses. But the degree of technological dependence is also high in Oceania, where R&D outlays are relatively small. Looking at ranking correlations between the level of R&D activities and the degree of technological dependence is difficult. However, if we look at this according to the different industries, R&D-intensive industries where relatively large R&D outlays are observed--chemicals, electrical machinery, transportation machinery--do not rely heavily on local businesses for their technology, whereas there is a high degree of technological dependence in the fields that are heavily reliant on local raw materials and resources such as food products, lumber, paper, and pulp. It generally follows that we can view outlays for overseas R&D as a substitution, not a supplement, for the introduction of technology from local businesses. In other words, the main factors underlying the implementation of overseas R&D have to do with motives other than direct technology introduction from the region.

Figure 3-3 Reasons for Establishing Overseas R&D Strongpoints



A: To search for leading-edge seeds
B: To accelerate the development of products that meet the needs of the market
C: To utilize local personnel and other resources
D: To exploit the merits of the high-valued yen
E: Other companies are active
F: Local demands
G: Difficult to establish in Japan
H: Other

According to the aggregate results used in this research study from last year's "International R&D Trends Questionnaire Survey" (valid samples collected from 345 companies, effective recovery rate 23%), there was a noticeably large number of companies that gave the following three reasons for establishing overseas R&D strongpoints: "to search for leading-edge seeds" (81.0%), "to facilitate the development of products that meet the needs of the market" (76.2%), "to utilize local personnel, facilities, and equipment" (63.1%) (Figure 3-3).

The suitability of the results of this investigation can be confirmed with data from other questionnaire surveys. For example, in the "R&D Internationalization Questionnaire Survey" that the Nihon Keizai Shimbun Company carried out in 1988, the three highest percentages of replies to the question of why the company was establishing overseas R&D strongpoints were: "it is easy to obtain overseas R&D information," "development of products that meet the needs of overseas markets can be promoted," and "it is easy to employ excellent foreign researchers."

In chemicals, electrical machinery, transportation machinery--the R&D-intensive industries--absorbing local technology is not the objective in the R&D development resulting from the establishment of overseas research labs by Japanese businesses. The objectives are either to grope in the direction towards independent R&D or to cope with the type of development that grasps the needs of the local market. Furthermore, those industries are clearly conscious of the utilization of local personnel and other resources for those purposes.

From the data above we can surmise that with businesses there is a tendency to scatter R&D strongpoints and a tendency to use strategy, namely new R&D development that results from the utilization of non-Japanese personnel, who have different cultures and traditions and who are expected to have a different concept of and approach to S&T. In that it is evident that business is pushing for more direct cooperation, on par with that of the U.S. and Europe, in its objectives, i.e., searching, and coping with market needs.

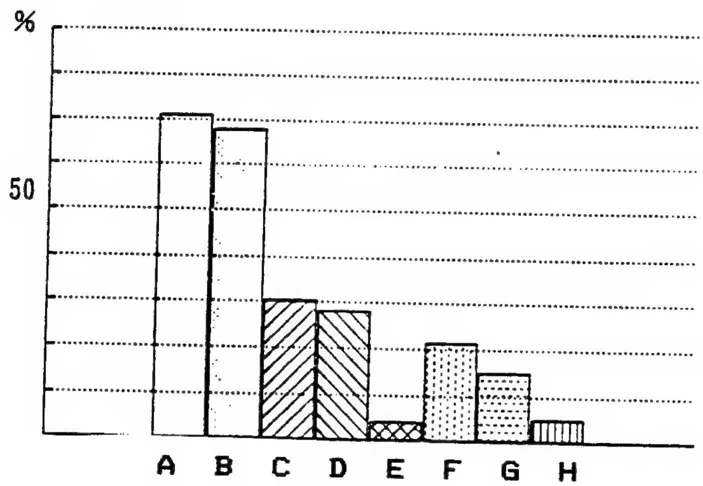
3-5 International Exchange

In the situation where research labs are located overseas for the purpose of carrying out searching-type R&D, it is clear that the objectives are of the same nature as those of international joint research and other such international exchange by businesses.

From the "Questionnaire Survey" mentioned previously, about 71% of the businesses surveyed replied that "searching for leading-

edge seeds" was their reason for implementing joint international research, and about 68% answered, "to facilitate development that corresponds to the market," as shown in Figure 3-4.

Figure 3-4 Reasons for Implementing International Joint Research (All Samples)



A: To search for leading-edge seeds
B: To facilitate development that corresponds to the market
C: To alleviate the burden of R&D expenditures
D: To disperse the risk involved in research
E: Other companies are active
F: Demands from partner
G: Joint research in Japan is difficult
H: Other

More so than the objective of introducing technology that is owned by foreign companies, the objectives of international exchange in Japanese businesses' R&D are primarily to exchange information and knowledge for the purpose of subsequent R&D evolution and then for the ensuing technology development.

It is easy to assume that the exchange of people plays a crucial role in this.

Actually, according to the "Questionnaire Survey" mentioned previously, about 45% of the businesses that responded said that they have had the experience of exchanging researchers. And, from their outlooks for the future:

- will increase considerably 25%
- will increase slightly 50%

75% of the businesses that responded foresee an increase in the exchange of personnel with foreign countries.

We can say that this indicates an attitude that will actively take on the challenge of activating R&D by exchanging people with foreign countries so that international exchange in the future will promote searching-type and market-needs-grasping-type R&D.

The internationalization of R&D activities is changing: instead of dealing with the introduction and acceptance of overseas technology, it deals with trying to form a "spot" for creating new scientific knowledge and technology that is based on direct exchange with researchers from overseas.

We can say that Japan's R&D that has unfolded under non-governmental leadership is establishing a new era through this kind of direct overseas exchange by businesses themselves.

Chapter 4. R&D Interrelationships

In the investigations of the previous chapters we supposedly looked at the relative retrogression of the U.S. position as an international R&D center, the concurrent spread of R&D strongpoints to Japan and Europe, and other such changes. In this chapter, we will explore how interrelationships among these R&D activities manifest themselves and what kinds of backgrounds lie behind those changes.

We thought that the circumstances surrounding those changes would come more clearly to the surface in the technology domains that have suddenly emerged in recent years, more so than in technology domains that are already in the mature stages. So, the following major, leading-edge S&T fields were the subjects of this investigation:

1) computer science
2) the life sciences
3) superconductors

The aerospace field, which is a leading-edge S&T field while at the same time one that necessitates international cooperation, was also a subject in this investigation.

4-1 Changes Seen in the Field of Computer Science

4-1-1 Changes Seen in the Numbers of Research Papers

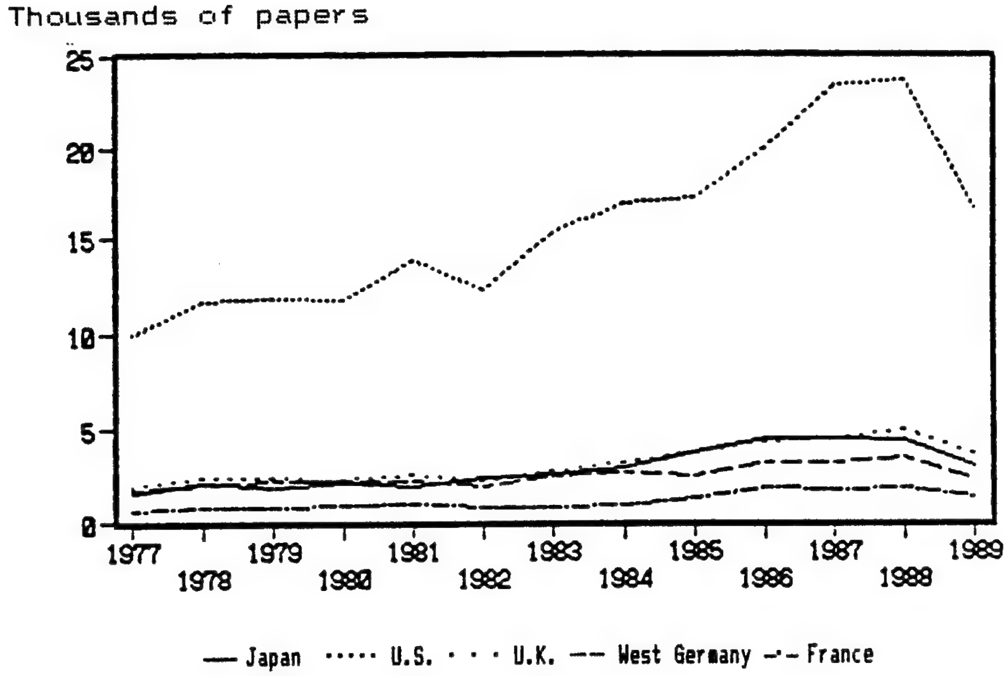
Here we will conduct an international comparison of the numbers of research papers in the field of computer science, which we define as those fields pertaining to computer hardware, computer software, applications, control technology, and systems and control theory.

Figure 4-1-1 shows the changes in the numbers of research papers in the field of computer science, based on the definition above, with respect to the five developed countries.

As is clear from this diagram, the U.S. is proud of the overwhelming scale of the number of its computer science papers in comparison with the other countries. From 1977 to 1989 it has been consistently publishing five times more papers than the other countries. Meanwhile, except for France, the other three countries exhibited the same kind of trend until 1984; in that year Japan and the U.K. started producing more papers than West Germany, where the number of papers declined.

Next, Table 4-1-1 shows the changes between 1979 and 1989 in each country's share of research papers.

Figure 4-1-1 Changes in the Numbers of Research Papers in the Field of Computer Science



Note: See *1 for data sources

Table 4-1-1 Changes in Shares of Research Papers in the Field of Computer Science

	Japan	U.S	U.K.	W. Germany	France
1979	9.4	62.3	12.7	11.4	4.2
1989	11.2	61.6	13.7	8.5	5.0

* Data source same as Figure 4-1-1

Over the last ten years the U.S. and West German shares in the number of the world's research papers declined while those of Japan, the U.K., and France grew, but there is still a tendency for the international R&D strongpoints in the field of computer science to be concentrated in the U.S. These five countries, whose combined shares amount to 60% of all papers, are in a ruthlessly competitive relationship. Over the last ten years the number of research paper announcements increased by 69.5% in Japan; 41.0% in the U.S.; 52.8% in the U.K.; 5.8% in West Germany; and 68.8% in France. The height of the increases in

Germany; and 68.8% in France. The height of the increases in Japan and France stand out.

The changes and fluctuations of R&D strongpoints among each of the countries are as previously described, but what kinds of situations exist within the individual countries? We will try to give a general outline of the trends of main R&D bodies within each country, categorized by sector, i.e., industrial, government, and academic. Table 4-1-2 shows the number of papers by sector in 1979, 1984, and 1989. Table 4-1-3 shows the same in terms of shares.

Table 4-1-2 Changes in Numbers of Research Papers By Sector

		Japan	U.S	U.K.	W. Germany	France
1979	Business	459	3,429	392	464	20
	Universities	930	5,727	1,381	897	318
	Other	412	2,720	658	809	466
1984	Business	973	5,343	599	666	21
	Universities	1,314	7,585	1,605	1,039	333
	Other	642	4,125	1,017	989	607
1989	Business	866	2,763	412	532	16
	Universities	1,408	9,988	2,218	1,091	438
	Other	779	3,997	1,085	673	903

* Data source same as Figure 4-1-1

Universities are the strongpoints where research papers are produced in all of the countries except France. In the U.K. and France, the business sector generates few papers. Particularly in France, the number of papers from the business sector is extremely low, and announcements of papers by researchers of mostly public organizations account for the mainstream.

During the last ten years in Japan, the academic sector's share of papers shrunk while that of the business sector grew. It appears that there has been a relative decline in R&D at universities while R&D by the business sector is becoming more vigorous.

As for the situation in the U.S., until 1984 it showed almost the same kind of shifts as in Japan, but by 1989 there was a great change in the appearance of things. It suggests a move by the U.S. to strive for perfection in its basic research, centered on universities, in response to Japan's dash ahead into the field of computer science.

Table 4-1-3 Component Ratio Changes in the Numbers of Research Papers By Sector

		Japan	U.S	U.K.	W. Germany	France
1979	Business	25.49	28.87	16.13	21.38	2.49
	Universities	51.63	48.22	56.80	41.34	39.55
	Other	22.88	22.91	27.07	37.28	57.96
1984	Business	33.22	31.33	18.60	24.72	2.19
	Universities	44.86	44.48	49.83	38.57	34.65
	Other	21.92	24.19	31.57	36.71	63.16
1989	Business	28.37	16.50	11.10	23.17	1.18
	Universities	46.12	59.64	59.70	47.52	32.28
	Other	25.52	23.87	29.20	29.31	66.54

* Data source same as Figure 4-1-1

Meanwhile in Europe, a tendency towards activation of non-business-sector R&D activities in the U.K. and France can be seen. The trend in France is distinguished by a consistent, government-led R&D system.

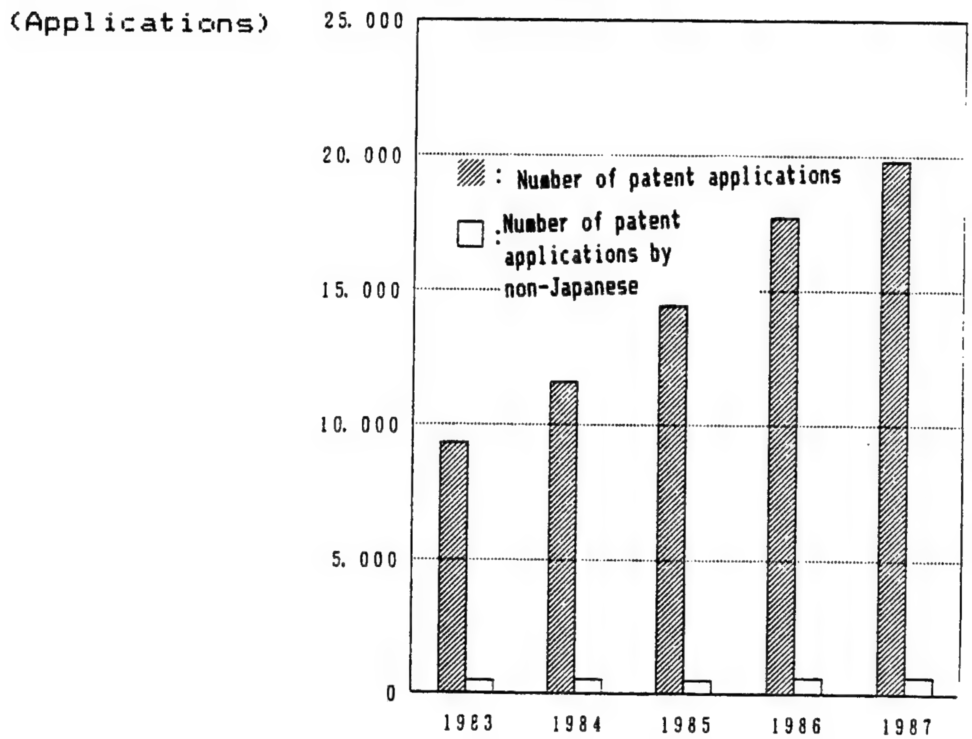
From the trends in computer science research papers discussed above, it appears that the strongpoints for active R&D are still concentrated in the U.S.; and that, in contrast to the U.S. and Europe, where the relative weight of the main R&D bodies is shifting to universities and public research organizations, Japan is tending to have more weight in its business sector. From this we can see some of the structural differences in the R&D systems.

4-1-2 Changes Seen in Patents

Of all the indicators of results from the field of computers, we took up research papers, which are heavily tinged with the flavor of science, in the previous section's comparisons of each country. In this section, however, we will compare Japan and the U.S. with respect to patent trends.

Figure 4-1-2 shows the changes in Japan's patent applications in the computer field. Here we used the numbers of patent applications in the G06 category, which is the Japanese patent classification for "computations; calculations," as an example that represents the computer field.

Figure 4-1-2 Japan's Patent Applications in the Computer Field



* The computer field comes under the G06 (computation) Japanese patent classification
Data: Patent Office bulletins

As seen in the diagram, patent applications in the computer field have been steadily growing in Japan since 1983 and have doubled in five years. Yet the number of patent applications by foreigners has been moving between 500 and 600, and the weight of that percentage is decreasing from year to year: in 1983, foreigners submitted 5.1% of the patent applications in Japan; in 1984, 4.6%; in 1985, 3.5%; in 1986, 3.4%; in 1987, 3.2%. In comparison with the U.S. and Europe, the percentage of foreigners filing patent applications is extraordinarily low in Japan, but compared to the percentage of all patent applications that are filed by foreigners in Japan, 8.8%, that for the computer field is an even lower figure. The peculiarities in Japan's patent applications have already been mentioned a number of times in previous chapters. The tendencies in the computer field are a typical representation of those trends.

Next, we will look at the trends in computer patent applications in the U.S. Table 4-1-4 shows the number of patents registered under the U.S. patent classification "Office Computing & Accounting Machines," which represents the computer field.

Table 4-1-4 U.S. Patent Registrations in the Computer Field

	1978	1988
Number of registrations	1,456	2,826
Percentage	2.20	3.63

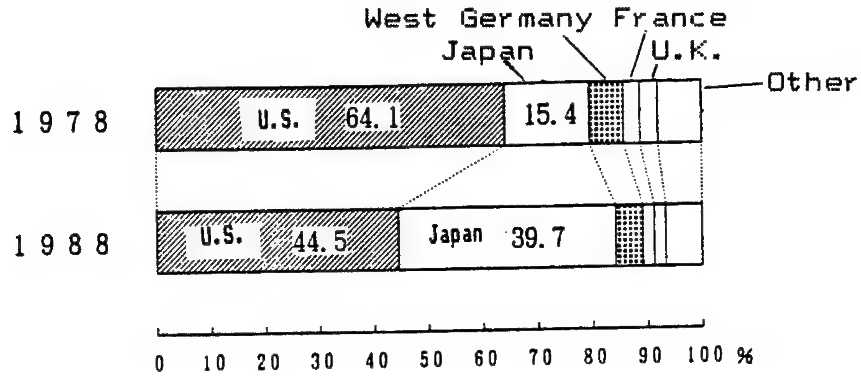
* The percentages shown are the percentages of all patent registrations that computer patents account for.
* The computer field comes under the U.S. patent classification "Office Computing & Accounting Machines."

Data: USPTO

The number of U.S. patent registrations in the computer field increased by about twofold from 1978 to 1986. Next, the percentages by nationality of patent registrants are shown in Figure 1-4-3.

In 1978 foreigners registered 35.9% of the U.S. patents in the computer field, but that rose to 55.5% by 1988. The share that especially grew was that of Japan: a 25% increase can be seen over the last ten years. The shares of European countries are declining slightly, and we can say that the structural change in the patent registrants of the U.S. is solely due to the strong influence of Japan's tendencies.

Figure 4-1-3 Percentages of U.S. Patent Registrants in the Computer Field, By Nationality



* The computer field comes under the U.S. patent classification "Office Computing & Accounting Machines."

Data: USPTO

We cannot adequately compare the patent trends of Japan and the U.S. because of the differences in the fields that are the subjects of the data used here, the differences between applications and registrations, the differences in the comparison years, and other such disparities. But, as an extremely macro way of looking at the trends, we can give the following as characteristics.

That foreigners account for a very low percentage of Japan's patent applications and that there is a tendency for that percentage to decrease over the years may indicate that Japan is continuing to strengthen its R&D activities and is continuing to grow as a strongpoint for industrial technology R&D in the computer field. This may also be supported by the fact that the percentage of U.S. patent applicants who are Japanese is dramatically increasing. Historically, the U.S. had been proud of its overwhelming superiority in the field of computer science, but lately there has been a relative decline in that power. In other words, we can say that R&D centers are continuing to spread over to Japan. A very important factor in that may be the vigor of Japanese businesses with respect to the development of technology.

4-1-3 What Caused the Changes, and International Competition and Cooperation

It is difficult to comprehend each country's situation in such a way as to take into account all the many technical fields within the domain of computer science, but here we will give a general outline of the trends in each country's S&T policies and systems

that individually pertain to computer science.

(1) U.S. Trends

In order to strengthen its international competitive power, the U.S. is consistently emphasizing basic research, with the promotion of S&T as an important support. Computer science is no exception, especially its priority areas--artificial intelligence, supercomputers, VLSI, software engineering. Basically, the U.S. is striving to promote R&D that is based on cooperation among industry, government, and universities; a large amount of financial support from the government--primarily the Pentagon--is being granted for R&D at private corporations.

In 1989 the total amount of the Federal Government's investments in R&D rose to $60.3 billion. Of that, 48.3% of went to private businesses and 90.4% was allocated for R&D (Science and Engineering Indicators - 1989).

Table 4-1-5 shows the changes in government development investments in computer science.

Unfortunately R&D-related data was not grasped, but over about a ten-year period investments in basic research increased nearly fourfold; investments in applied research, twofold. This means that government policies are stressing basic research in computer science as well.

Table 4-1-5 Government-Defrayed Computer Science Research Expenditures in the U.S. (Millions of Dollars)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Basic research	46	52	67	90	105	116	131	129	143	182
Applied research	82	69	104	124	110	164	171	169	172	182

* 1988 and 1989 data are estimated values

Data: Science and Engineering Indicators - 1989

On the other hand, the number of researchers in the field of computer science increased by nearly threefold from 1976 to 1983; if we look at this data by sector, the jump in the number of researchers employed by the business sector is conspicuous (Table 4-1-6). These figures are thought to indicate the results of a considerable portion of development investments by the government, centering on the DOD, going into private enterprises' R&D.

Table 4-1-6 Number of Researchers By Sector in the U.S.

		Business	Educational Organizations	Government Organizations	Other
1976	Number of people	86,800	6,900	9,300	16,000
	Percentage	72.9	5.9	7.8	13.4
1983	Number of people	276,500	19,700	24,500	28,400
	Percentage	79.2	5.7	7.0	8.1

* The percentage values are the breakdowns (%) for every year

Data: Science and Engineering Personnel, NSF, 1985

What kind of steps are being taken lately to strengthen R&D in computer science? As an example we will try to track the trends in policies concerning semiconductor development.

The high-speed integrated circuit program and the gallium-arsenide IC program are representative examples of government programs involving the development of semiconductor technology. A project that the DOD has promoted, the high-speed integrated circuit program was started in 1980 and is being continued intermittently until 1990; the objective is to assign military-use VLSI development to the private electronics industry and to ensure the level of the technology. The gallium-arsenide IC program, a DOD-promoted project that was started in 1981, is in the production phase after basic research ended around the middle of the 1980's. However, universities and independent research organizations are not participating in this project; it is limited to a few major military contractors.

On the other hand, the Semiconductor Manufacturing Technology

Joint Development Organization (SEMATECH) and the Semiconductor Research Consortium (SRC) are representative of industrial-governmental or industrial-academic cooperation systems. SEMATECH, the objective of which is to maintain the U.S. semiconductor industry's international leadership, is an R&D organization in which semiconductor manufacturers and the DOD participate. The idea is that its research results are to be transferred to the member enterprises. SEMATECH's management formula involves having the members all dispatch their excellent R&D personnel; the members and the government split the $250 million in yearly expenses. It is the first case of the government providing financial support directly to a private industry consortium.

The SRC is a non-profit association that was organized in 1982 around enterprises belonging to the U.S. Semiconductor Engineering Society. Its objective is to provide financing to universities for basic and general R&D that relates to semiconductors. It protects both sides' profits: universities turn the results of their R&D into patents and then offer the licensing rights to the enterprises.

Although it is somewhat different in nature from these measures for strengthening R&D, the Semiconductor Chip Protection Act was enacted in 1984 in connection with the strengthening and protection of the intellectual property rights to semiconductor technology. Needless to say, this represents a part of the protectionist policies against Japan's threat in the field of semiconductors.

(2) Japan's Trends

Table 4-1-7 shows the changes in Japan's research expenditures in the field of information processing.

It shows that the total amount of research expenditures grew by more than fivefold from 1977 to 1987. Looking at it by sector, the sudden increase in the usage weight of companies and the decrease of research organizations' weight are remarkable. These changes correlate with the shifts in the numbers of research papers in the field of computer science. We can say that the trends in computer science are an example that points directly to Japan's private-sector-led R&D structure.

On the other hand, government-promoted joint research in universities and corporations is becoming a central theme of government S&T policies in Europe and the U.S., but what about in Japan? Table 4-1-8 shows the research in the software field that was implemented under joint research systems (Ministry of Education).

In terms of the number of joint research endeavors during FY 1988, the software field was third after joint research related to materials development (184 projects) and machinery development (141 projects), but the absolute number of joint software projects was very small. As a system for bridging the distance between basic research in universities and development research in private firms, the state of Japan's joint software research is still in the early stages of development when compared with the situations in Europe and the U.S.

Nevertheless, Japan, too, is making steady progress in systems for promoting basic R&D in leading-edge fields, systems that are aimed at international contributions through R&D, and government-led R&D projects. It has implemented computer-science-related research themes in systems such as the Creative Science Promotion System that started in 1981, the Next-Generation Industrial Base Technology R&D System, and the Human Frontier Science Program. As for government projects, the Fifth Generation Computer Project, the Machine Translation System Development Project, the Foodstuff Industry Technology Inspection Support Expert System Development Project represent some of the projects that are in progress.

(3) Europe's Trends

In the U.K., electronics and information technology are one of the government's highest priority themes. Under the linkage of the Ministry of Trade and Commerce and the Council for Science and Technology, the British government established the Joint Framework for Information Technology, a combined research project, and is providing aid for those R&D activities. This project consists of several programs. An example is the Joint Optoelectronics Research Scheme that ended in 1989; it brought forth great research results in connection with optical switches, optical integrated circuits, optical fibers, etc. In another, the Alvey Program, which corresponds to Japan's Fifth Generation Computer research, with government support corporations and universities are carrying out joint research on VLSI's, knowledge information processing, and intelligent man-machine interfaces. Meanwhile, with technology transfer as the main objective, the Ministry of Trade and Commerce is promoting activities such as the Regional Electronic Centre, which was established in 1986; the Surface Mount Club, also set up in 1986; and the Electronics CAD Initiative, which started in 1986.

France is encouraging joint research that uses EC organizations more so than direct financial support. It is also on a course that deals with S&T as an EC issue; its basic plan is to maintain harmony with the S&T policies of all of Europe. The bedrock of France's high-tech development is an approach that thoroughly stresses basic science. Consequently, France will lead other

Table 4-1-7 Japan's Expenditures for Research in the Field of Information Processing (Millions of Yen)

	Companies, etc.	Research Organizations	Universities, etc.	Total
1977	81,903 (70.5)	29,784 (25.6)	4,539 (3.9)	116,226 (100.0)
1982	199,998 (80.1)	41,449 (16.6)	8,307 (3.3)	249,754 (100.0)
1987	554,455 (91.7)	30,930 (5.1)	19,286 (3.2)	604,671 (100.0)

* Companies that were the subject of the data shown have at least 100 million yen in capital
* Figures in parentheses are the percentages for each sector
* The years shown are fiscal years

Data: Patent Office, Statistics Bureau "Investigative Report of S&T Research"

Table 4-1-8 Software-Related Joint Industry-Academia Research

	1983	1984	1985	1986	1987	1988
Number of projects	8	15	24	30	48	80
Percentage	14.3	9.4	11.1	11.0	12.1	13.7

* The years shown are fiscal years
* The percentage is: (Number of software projects)/(Total number of projects)

Data: State of implementation of "Private and Other Joint Research"

countries in fields like nuclear energy and aerospace, where basic research is directly connected with the final product, but in fields such as computer science, where there is considerable distance between R&D and the final product, it will be forced into sluggishness. In order to solve this kind of problem the French government is putting more energy into the EUREKA projects, which center on the EC. France has also been the advocate of these projects and is participating in 106 of the 203 projects. Its 85 million francs in financial support is the largest amount from any of the 18 countries participating in the projects, too (FY 1988). At the same time France is becoming more energetic lately in its moves to narrow the gap between public research organizations' research and applied research, and to improve joint research between industry and universities through the exchange of human resources. Concretely, those moves involve the Scholarship System for Cultivating Researchers (CIFRE), where the government pays out scholarship funds as salaries for pre-doctoral researchers whom industries employ for a fixed period of time; and the System for Cultivating Researchers Through Cooperation between Industry and Universities (FIRTECH), a system that was started in 1984 where industry, the government, and universities form cooperative groups for each research theme and can jointly use research personnel and facilities. Incidentally, CIFRE involved 550 cases in FY 1989, of which electronics accounted for the most (25%).

The R&D policies of the West German government involve promoting basic research that will become the key to the future, increasing private R&D, and promoting the participation of small and medium-sized businesses in R&D. Typical examples of the government's financial support in the field of electronic information and communications technology are the Special Project for Promoting the Utilization of Micro-Electronics, which has been carried out since 1982; and, since 1984, the Five-Year Project that is aimed at all-around progress in micro-electronics, information technology, and communications technology. The Federal Research and Technology Agency and the Federal Posts and Telegraph Agency are mainly implementing and striving to promote R&D in this field by the private sector, but the German Research Society is the organization who supports that R&D. Although the German Research Society provides financial support for research projects in all scientific fields, most of that money is used for university research expenditures. The society is also striving to strengthen cooperative systems for researchers in various scientific fields and to promote balanced basic and applied research.

The EC's R&D projects, the purpose of which is to promote joint projects among all of Europe's countries, also play an important role in Europe's R&D trends in the fields of computer science, electronics, information, and communications. Some of those main

Table 4-1-9 Joint R&D Projects of Europe

EUREKA Projects

Objectives: To foster European industries, improve the productive and competitive power of each country's economy, and strengthen the foundation for prosperity and employment, by means of joint research among European businesses and research organizations.

Time period: 1985 - 1996

Number of projects: 298* projects are in progress (1989)

Scale of budget: Estimated at about 8.0 billion ECU

Research domains:
- Product technology and robots
- Information technology
- Heat and power technology
- Materials technology
- Education
- Computer technology
- Laser engineering
- Environment-related technology
- Transportation technology
- Biotechnology

Remarks: Participating members are the 12 EC countries, five countries of the European Free Trade Association, Turkey, and 20 members of the EC Committee.

* Includes the JESSI project

ESPRIT Projects

Objectives: To activate information and communications technology, which lags behind that of Japan and the U.S., and to ensure the international competitive strength of the EC's information and communications industry, by means of joint research among the industries, governments, and universities of each of the EC nations.

Time period: 1983 - 1992

Number of projects: 224 projects are in progress (1989)

Scale of budget: 1.6 billion ECU (1988 - 1992)

Research domains:
- Software technology
- OA (office automation) systems
- Leading-edge information processing technology
- Computer-integrated manufacturing
- Advanced micro-electronics technology

Remarks: To receive ESPRIT financial support, research groups must consist of at least two mutually independent enterprises of different nationalities.

RACE Projects

Objectives: To build ASDN and IBC networks throughout Europe by 1995, by means of joint research among the electrical and communications businessmen and corporations of the EC nations.

Time period: 1985 - 1992

Number of projects: 89 projects in progress (1988 - 1992)

Scale of budget: 550 million ECU (1988-1992)

Research domains:
- High-speed LSI's
- Superlattice LSI's
- Optical IC's
- Broadband exchange equipment
- Line control programs
- Large-screen display panel technology, etc.

programs are the ESPRIT (1984) and the RACE (1987) projects. As programs aimed at supplementing ESPRIT and RACE and making the most use of the results from those two programs, there are the DRIVE (1988), AIM (1988), and DELTA (1988) projects. Research themes in the fields of computer science, electronics, information, and communications are also incorporated in projects other than the EC projects, e.g., the EUREKA (Europe Research Cooperation Organization), and COST (European Cooperation in Science and Technology) projects.

(4) A View of International Cooperation

As the analyses above have made clear, it is no exaggeration to say that computer science R&D is led by the overwhelming strength of the U.S.

However, changes are seen in the structure of international R&D, as witnessed in the increase of Japan's R&D strength.

1) The R&D strength of the U.S. is tremendous in both basic and applied research in the field of computer science, and it has led the development of the entire world.

   Furthermore, the support of the U.S. government has played a great role in the growth of computer science, and attention is drawn to the fact that the technological development attributable to U.S. businesses has accelerated that growth.

   Through the release of many research papers on computer science and through the opening to the public of patents, this U.S. leadership has stimulated the world's R&D.

   This leadership is also obvious in the market expansion that is attributable to U.S. business. Great roles have been played by the Cray company in the field of supercomputers; by IBM in large and middle-size computers; and by others such as Unix and Amdahl.

   In the U.S. and Europe, where it accounts for 70% and 40%, respectively, of the mainframe markets, IBM has especially propelled the evolution of computer technology.

2) Meanwhile, Japan has been concentrating its energy on R&D for the purpose of catching up with the U.S. It is striving for technological development in the area of mainframes through IBM-compatible lines. In small and personal computers it has formed a large niche in the global market as a result of its own technology.

Japanese businesses are playing an extremely large role in the evolution of computer science in Japan.

In Europe, too, computer science centers on business as a result of government aid to European firms, which started with the Siemens company of West Germany, and powerful countermeasures based on joint European projects. Computer science in Europe is developing in such a way that the commercialization of more realistic systems is a central issue.

As this kind of business expansion by corporations proceeds, footholds have emerged in both Japan and Europe for expanding basic research in computer science.

For example, in Japan it is becoming possible to push forward independent R&D for next-generation science, e.g., parallel computers, inference machines, etc. Research personnel have also become more competent. And, as with fuzzy systems, evolved technologies are not few in Japan.

3) Nevertheless, the developments in Japan and Europe have become something for the U.S. to watch closely as a manifestation of competitive factors.

The U.S. measures to strengthen the protection of intellectual property rights are being powerfully pushed from this kind of background. The strong demands by the U.S. for the protection of programs, through copyrights and the protection of corporate secrets, have been thrust before Japan and Europe as even political counter-measures.

In response to U.S. demands, Japan and Europe are sincerely coping with the situation and are confronting the evolution of new international harmony.

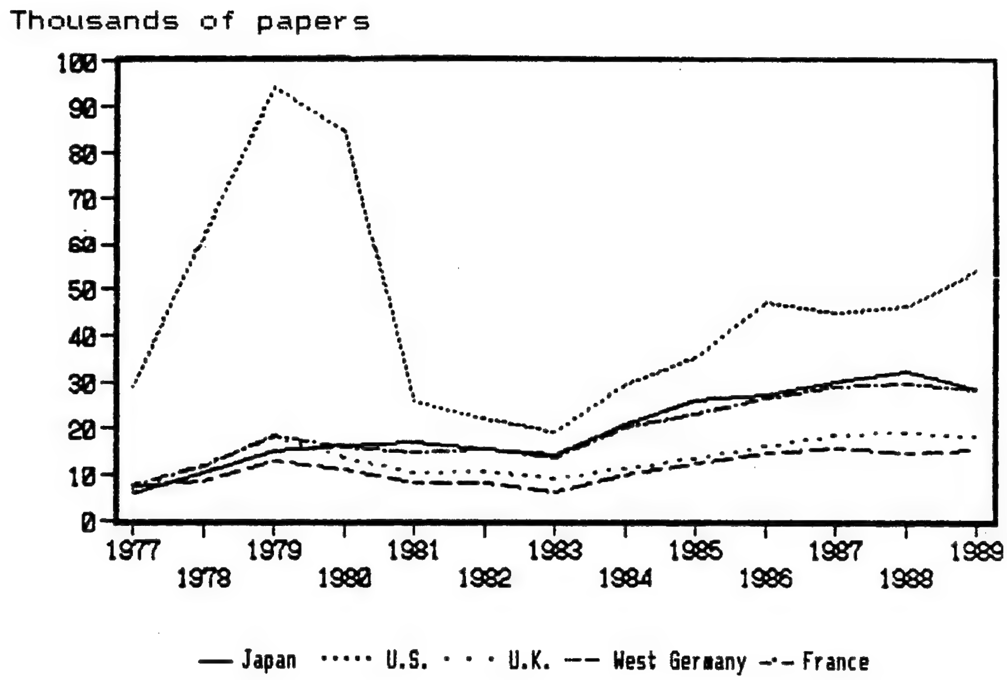
We cannot deny that Japan and Europe still are not as good as the U.S. in software R&D strength, though they have reached nearly the same level as the U.S. in computer hardware technology. And, the differences in the ways that Japan and Europe cope with the IBM and Unix groups of the U.S. in connection with the standardization of operating systems are making future models for international harmony complicated.

4-2 Changes Seen in the Life Sciences

4-2-1 Changes Seen in the Numbers of Research Papers

As revealed in Figure 4-2-1, which shows the changes in the numbers of research papers in the life sciences, the number of papers from the U.S. is overwhelmingly larger than that of other countries. In particular, there were five times more announcements of research papers in the U.S. than in other countries during the three-year period that peaked in 1979. The life sciences, incidentally, is a domain that encompasses various fields such as biology, medicine, and agriculture. Biotechnology-related fields, starting with genetic manipulation and cell fusion, are those fields of the life sciences where R&D activities have suddenly become vigorous in recent years.

Figure 4-2-1 Changes in the Number of Research Papers in the Life Sciences



Note: See *1 for data sources

Although we cannot grasp what the contents of the research papers are from the data in Figure 4-2-1, if we consider the sudden changes occurring in the U.S., and the fact that the shifts in the other countries' trends in research paper announcements can be viewed as a point of inflection in 1983, we can think of biotechnology as being a main cause of the fluctuations in the

number of research papers in the life sciences, which is a domain with a very broad range of subjects.

At first, the U.S. was the central place for biotechnology R&D. Then, from the beginning of the 1970's there was a series of brilliant discoveries: genetic recombination became a reality in 1973, for example; in 1978 it became possible to use recombinant DNA technology to produce human insulin from *E.coli*. At the beginning of the 1980's recombinant DNA technology started to be utilized in an engineering-type of fashion in mainly medical and pharmaceutical fields (Table 4-2-1).

We can certainly say that these facts and the changes in the numbers of research papers seen in Figure 4-2-1 explain the trends in biotechnology. That is, the first half of the peak around 1979 signifies a period during which there was an enthusiastic surge of innovative basic research and research on the possibilities for that practical application. The latter half of the peak reflects the situation where advances were made in applied research that was aimed at commercial utilization and in research pertaining to the management of technology.

Table 4-2-1 Advances in Biotechnology

Science and Technology	Industry
1944 Proof that genes are made up of DNA (Avery, U.S.)	1956 Fermentation production of amino acid (glutamic acid) started (Japan)
1951 Amino acid sequence of insulin determined (Sanger)	
1953 Elucidation of the double helix structure of DNA (Watson, U.S.; Crick, U.K.)	
1956 DNA synthesis enzyme discovered (Kohnberg, U.S.)	
1957 Success in cell fusion using *Sendai* virus (Okata, Osaka University)	1957 Fermentation production of nucleic acid (5-inosinic acid) started (Japan)
1961 Genetic code of nucleic acid deciphered (Leninberg, U.S.; Ochoa)	Operon theory about the control mechanism of protein synthesis advocated (Jacob and Moneau, France)

Table 4-2-1 Advances in Biotechnology (cont'd)

Science and Technology	Industry
1969 Carrot cloned from a single carrot cell in a cell culture (Steward, U.K.)	1969 Production of L-Amino by fixed enzymes started (Japan)
1970 Reverse transcriptase discovered (Temin, U.S.)	
Restriction enzyme discovered (Smith, U.S.)	
1972 Development of cell fusion technology (Milzanshutine)	
1973 Recombinant DNA technology completed (Cowen and Boyer, U.S.)	
1975 Success in creating monoclonal antibodies with cell fusion (Melhyas, West Germany)	
1978 Success in creating a "pomato" with cell fusion (Melhyas, West Germany)	
Success in making *E.Coli* produce human insulin by means of recombinant DNA technology (Sakakura)	
1980 Success in making *E.Coli* produce interferon by means of recombinant DNA technology (Weissman and Gilbert U.S.)	1980 Announcement of technology that substitutes biotechnology for some petrochemical processes (U.S.)
1982 Birth of the super mouse (Parmitter and Prinster, U.S.; others)	1982 Production of insulin by recombinant DNA technology started (U.S.)

Table 4-2-1 Advances in Biotechnology (cont'd)

Science and Technology	Industry
1984 Development of recombinant DNA technology using plant and animal cells (Axel)	
1985 Success in artificial reconstruction of protein-dissolving enzyme (trypsin) (Frederick)	1985 Production of human growth hormone by means of recombinant DNA technology started (U.S.)
	Production of general-purpose chemical engineering products by means of fixed micro-organisms started (U.S.)
	1986 Production of alpha-interferon and Hepatitis-B vaccine by means of recombinant DNA technology started (U.S.)
	Production of amino acids by means of recombinant DNA technology started (Japan)
	1987 Production of TPA by means of recombinant DNA technology started (Japan)

Data: Bio-Industry Vision, MITI Investigations Council;
Biotechnology - The Current Situation and Development Directions, Central Bank for Agriculture and Forestry;
Nikkei Biotechnology - Current Terminology Dictionary; etc.

Next, Table 4-2-2 shows the changes in the countries' shares of the total number of research papers in 1979 and in 1989.

Table 4-2-2 Changes in Shares of Research Papers

	Japan	U.S.	U.K.	West Germany	France
1979	5.56	34.86	6.69	4.81	6.84
1989	6.41	12.05	4.10	3.48	6.30

Data: Same sources as Figure 4-2-1

In the last ten years the shares of the countries other than Japan have been dropping. The U.S. share has fallen by one third during the past ten years. In 1979 the total for the five countries accounted for 58.8% of the world total; in 1989 that declined to 32.3 percent--only one third of the world's research papers in the life sciences. Indeed, 1979 was a year when the U.S. number of papers went to an extreme peak, and the drop in that share a decade later is a matter of course. But even if we take that into consideration, it is obvious that research in the life sciences is spreading widely to countries throughout the world and is not limited to only the so-called developed countries. With progress being made in not only medicine and pharmaceuticals but in foodstuffs and agriculture as well, it is not hard to imagine that in the future biotechnology-related topics will become important in the S&T policies of developing countries that are rich in plant resources.

The tremendous number of research paper announcements in the U.S. during 1979 also points directly to the concentration towards an S&T field in its genesis and to a situation in which excellent research results are brought forth.

Owing to the strength of the U.S. during this period, we can also say that biotechnology, which got its start with recombinant DNA techniques, laid a foundation in powerful S&T methods.

There are also some incalculable effects in the repercussions that that strength brought about throughout the world.

Furthermore, we can think of the successive dimunition in the number of U.S. research papers, as if the tide is going out, as symbolic of the U.S. If we take one possibility to the limits, we can say that it clearly indicates the U.S. ideal, where researchers disperse to the next arena and head for exploration.

In recent years the strongpoints where research papers in the life sciences are produced have been continuing to scatter. In view of that diffusion, we will look at the kinds of changes taking place within individual countries. Table 4-2-3 shows the numbers of research papers by sector in 1979, 1984, and 1989; Table 4-2-4 shows the same in terms of shares.

Table 4-2-3 Changes in Numbers of Research Papers By Sector

		Japan	U.S	U.K.	W. Germany	France
1979	Business	785	1,917	407	290	258
	Universities	11,536	62,078	8,770	7,412	4,924
	Other	2,685	30,035	8,853	5,275	13,270
1984	Business	985	888	162	332	46
	Universities	15,998	19,000	5,836	5,172	4,808
	Other	3,930	9,615	5,563	4,531	15,620
1989	Business	2,259	3,944	418	773	190
	Universities	20,940	30,981	8,870	8,073	5,392
	Other	5,555	19,100	9,090	6,782	22,674

* Data sources are the same as those of Figure 4-2-1

In any of the countries, universities and "other" organizations (primarily public research organizations) are the main bodies where research papers in the life sciences are produced, and we may say that, from a macro viewpoint, there were no great changes in that trend over the past ten years. However, here again we come across a situation that indicates a fairly strong correlation between biotechnology's evolutionary process and the tendency for the number of life science research papers to change, as mentioned before. It is apparent in the number of research papers produced by the business sector, and in the fact that the weight of the business sectors in the U.S., Japan, and West Germany increased. In particular, the number of research

papers from the business sectors of the U.S. and West Germany increased 2-3.5 times during the past ten years. The fact that in the four countries other than West Germany the weight of the number of papers from universities decreased and the percentages of "other" (mainly public organizations) has increased since 1983 can also explain the shift from basic research to applied research and technology management.

Table 4-2-4 By-Sector Shares of Research Papers (%)

		Japan	U.S	U.K.	W. Germany	France
1979	Business	5.23	2.04	2.26	2.23	1.40
	Universities	76.88	66.02	48.64	57.12	26.69
	Other	17.89	31.94	49.10	40.65	71.91
1984	Business	4.71	3.01	1.40	3.31	0.23
	Universities	76.50	64.40	50.48	51.54	23.48
	Other	18.79	32.59	48.12	45.15	76.29
1989	Business	7.86	7.30	2.27	4.94	0.67
	Universities	72.82	57.35	48.26	51.66	19.08
	Other	19.32	35.35	49.47	43.40	80.24

* Data sources are the same as those of Figure 4-2-1

On the other hand, individual characteristics can be been in each country. In Japan, universities account for a much greater weight than in the other four countries; about three fourths of all the research papers in the life sciences are from universities. Universities' weight has been slowing decreasing every year over the past decade while the percentage for business and "other "

organizations is increasing. The tendency for universities' weight to decrease is also seen in the U.S. and in France, but France's structure differs considerably when compared with Japan and the U.S.

Of course the U.S. is also the type of country where universities provide the leadership in science, but the weight of its "other" organizations is great in comparison with Japan; the transitions over a decade indicate a trend where the gap between universities and "other" organizations is becoming smaller. Also, the number of research papers from the business sector has tripled over the past ten years. In contrast with the Japanese and U.S. types of structures in which research papers are generated, in the U.K. and West Germany the weight of universities rivals that of "other" organizations. In the U.K., particularly, there has been hardly any change over the past decade in the structure in which research papers are generated.

On the other hand, the structure in France differs greatly with that of the other four countries. In France research papers from "other" organizations account for a great deal of weight, followed by universities. Furthermore, another remarkable difference is that in France the number of research papers from the business sector is decreasing. As far as we can see from the comparison of numbers of research papers, "other" organizations, which center on national and public research organizations, have a central role in R&D activities in the life sciences in France.

From the by-sector and by-country comparisons of the numbers of research papers, it is clear that the world's leading life sciences R&D centers are scattering from the U.S. to each of the other countries. Furthermore, the main bodies that actively carry out R&D are different kinds in different countries. As for each country's state of affairs, it is probably necessary to not only grasp the actual state of a main R&D body's activities in a given country, but also to make a comprehensive analysis that includes the system and government policy factors in that background.

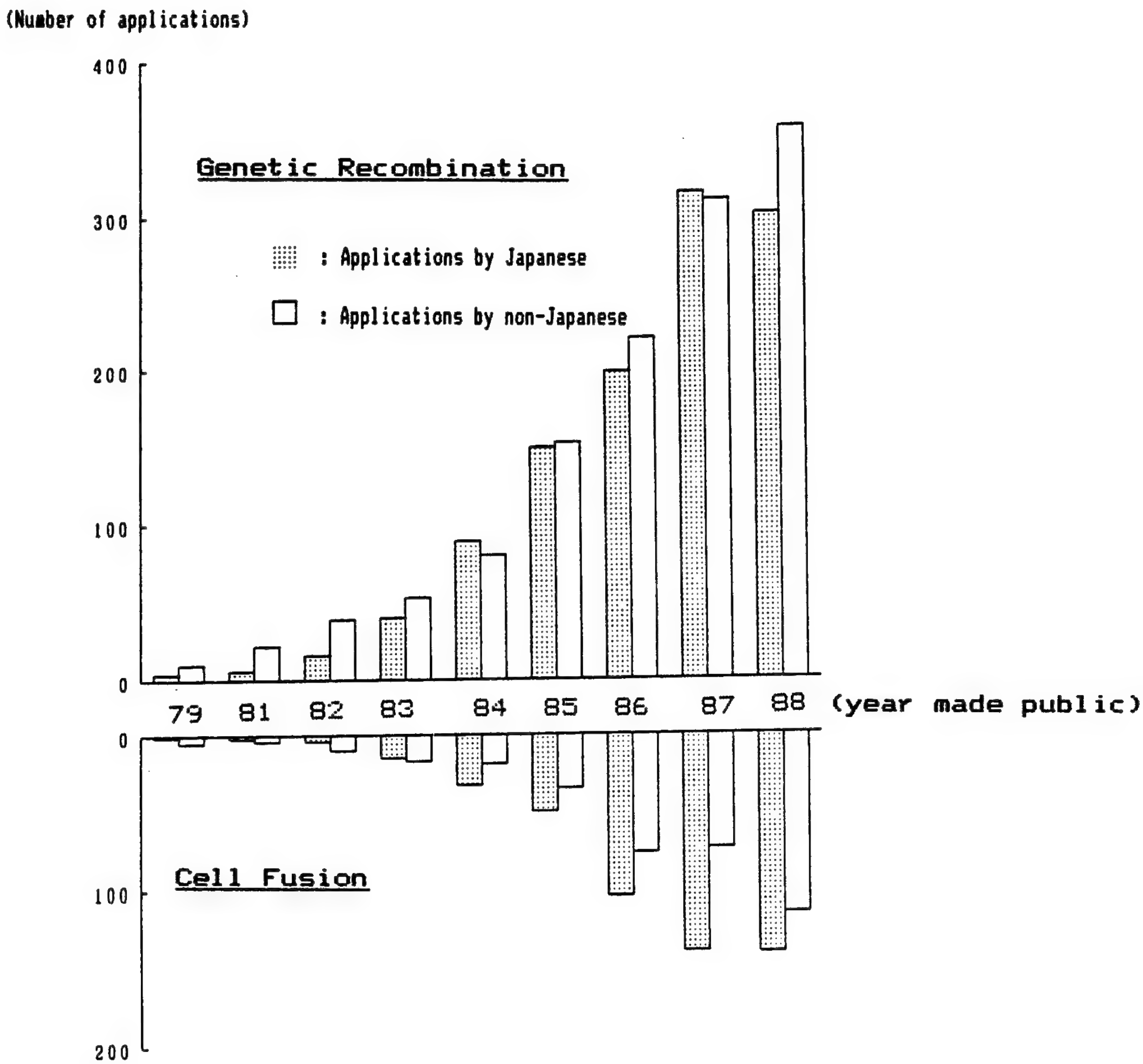
4-2-2 Changes Seen in Patents

Here we will take a general look at the trends in Japanese and U.S. patents related to biotechnology, an area within the life sciences that also shows rapid progress.

Figure 4-2-2 depicts the state in Japan of applications for patents on genetic recombination and cell fusion.

As can be seen from the diagram, since 1979 patents involving genetic recombination and cell fusion have been rapidly increasing in Japan. However, because the years shown are the

Figure 4-2-2 Changes in the Number of Applications for Biotechnology Patents in Japan



* From official reports on patent releases and announcements (patents released from 1969 to 1988)

years when the patents were made available to the public, the discoveries behind those patents were actually made about a year and a half earlier.

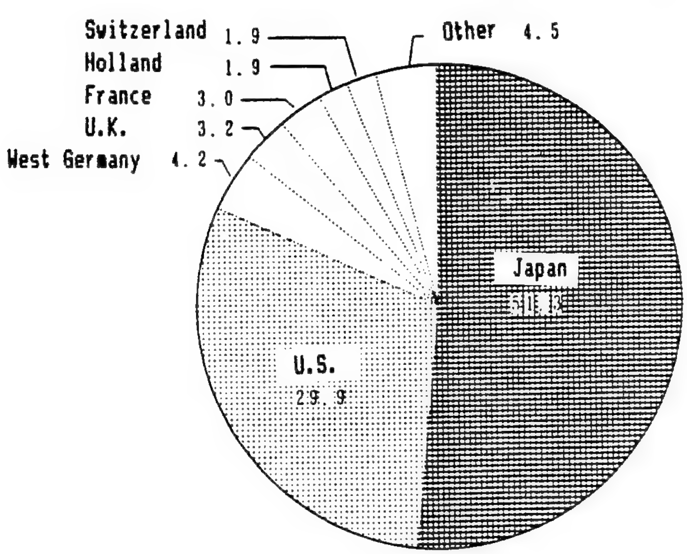
What is peculiar about this data is that there are very many applications submitted by non-Japanese.

If we look at all patent applications in Japan, the percentage of applications by foreigners has hovered around 10% during the past two to three years, e.g., in 1988 the percentage of applications by foreigners averaged over all fields was 9.0%. However, in the field of genetic recombination, that number was about 50%. In particular, if we speak about those patents that were made public in 1985 and 1986, applications by foreigners exceeded those by Japanese. In the field of cell fusion, too, applications by foreigners greatly surpassed the average percentage of applications by foreigners. Although the overall trend in Japan's patent applications is for the percentage of applications by foreigners to be extremely low in comparison with other countries, the percentages in the field of biotechnology are about the same as those in Europe and the U.S. This suggests that Japan has been placed in an intensely competitive relatioship.

Figure 4-2-3 is a breakdown of the nationalities of the applicants who applied for biotechnology patents in Japan.

This is the result from summing all the applications in the field of genetic engineering that were released by December 1987. Applications by Japanese account for only about half of the total number of applications. Of the remaining 50% or so of non-Japanese applicants, 29.9% were submitted by Americans, 4.2% by West Germans, 3.2% by British, and 3.0% by French.

Figure 4-2-3 Percentages By Nationality of Patent Applicants in the Field of Genetic Engineering



* Total of applications that were made public by December 1987

On the other hand, what are the trends in U.S. biotechnology? Table 4-2-5 shows the state of patent registrations in the field of genetic engineering; Figure 4-2-4 shows the percentages by nationality of patent registrants.

The number of genetic-engineering-related patent registrations in the U.S. increased by nearly tenfold between 1975 and 1986. Of the 70,860 patents in all that were registered in 1986, genetic-engineering-related patents accounted for 0.16%, but within a decade that percentage became ten times higher.

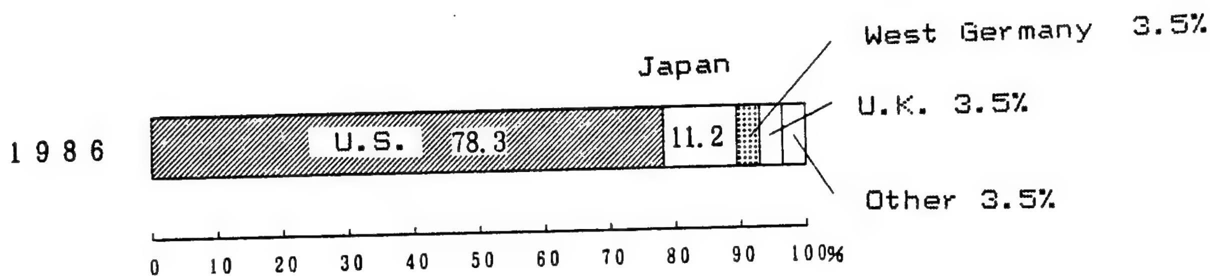
Table 4-2-5 State of Patent Registrations in the Field of Genetic Engineering in the U.S.

	1975	1986
Number of patent registrations	11	116
Percentage	0.015	0.164

* The percentages show the total number of patent registrations that are in the field of genetic engineering

Data: USPTO

Figure 4-2-4 Percentages By Nationality of Patent Registrants in Fields Related to Genetic Engineering in the U.S.



Data: USPTO

In 1986 only 21.7% of patent registrations were by foreigners. This situation in 1986 differs greatly with the trends in Japan's biotechnology-related patent applications during that same year. In the U.S. about half of all patent registrations were by

foreigners, but only about 20% of the patents in genetic engineering were registered by foreigners--a percentage much lower than the 53.8% for all patents. Therefore, we must say that the astounding power of the U.S. is displayed in connection with genetic engineering, in total contrast with Japan's situation.

Next, we will look at who makes up the applicants in both Japan and the U.S. Table 4-2-6 shows the by-sector composition of applicants in each country.

In 1980 universities and non-profit organizations were the main bodies in both Japan and the U.S. for patent applications in the field of biotechnology, but by 1988 that mainstream shifted over to business. In Japan there have always been few patent applications from universities, and the field of biotechnology is no exception: according to data from 1987, a mere 2% of the applications were from universities. Applications from non-profit organizations were at the same level in both Japan and the U.S. during 1987, but the presence or lack of patent applications from universities becomes a noticeable difference that appears.

Table 4-2-6 By-Sector Composition of Biotechnology Patent Applicants (%)

		Japan	U.S.
1980	Universities	8.0	28.6
	Non-profit organizations	48.0	21.4
	Individuals	4.0	10.0
	Business	40.0	40.0
1987	Universities	1.9	16.1
	Non-profit organizations	19.2	21.0
	Individuals	3.8	9.7
	Business	75.1	53.2

Looking at the year-to-year flow, in Japan patent applications by non-profit organizations have been suddenly decreasing while applications by the business sector are increasing by that amount. In the U.S. the decrease in applications by universities appears in the increase in applications by the business sector. Here, the differences in the roles that universities and public research organizations (non-profit organizations) play in both countries' R&D activities (R&D activities that go as far as patent applications) stand out in bold contrast.

4-2-3 What Caused the Changes, and International Competition and Cooperation

Of the research within the life sciences, biotechnology is expected to be the field where great technological development is possible. The rapid growth process of biotechnology that is centered on recombinant DNA technology stands out sharply in the trends in research paper announcements in the life sciences. This biotechnology envelops possibilities for tremendous development. Strategically, too, it differs with other S&T fields that are already maturing, and it greatly expands the possibilities for establishing a leadership position in R&D. On the other hand, because biotechnology is a research domain that deals with life itself, in promoting this research it is becoming necessary to give adequate consideration to its safe management.

To that end, governments' policy-making type of participation in the life sciences has a great significance with respect to:

1) establishing a leadership position in R&D activities, and

2) the regulation of R&D activities.

(1) U.S. Trends

The biotechnology R&D system of the U.S. is characterized by vigorous cooperation between industry and universities. That is, it is a system in which basic research by universities is commericialized by businesses. With regard to the cooperation between industry and universities, venture businesses have come to play a major role in the genesis of biotechnology that centers on recombinant DNA technology.

On the other hand, most of the government support for biotechnology R&D is directed towards strengthening basic research. The NIH is the main promoter of basic research; a considerable share of the basic research in the U.S. is shouldered by NIH researchers or researchers in graduate schools and other outside groups who receive support from the NIH. The

NIH is also in charge of over 80% of all R&D investments (1987 data, U.S. Council Report from 1988). Table 4-2-7 shows the state of the NIH's development investments in biotechnology research. The tendency for the government to view basic research as important can also be read from the fact that more than 60% of NIH investments are applied towards basic research.

Table 4-2-7 NIH's Investments in Biotechnology Development (Thousands of Dollars)

	1985	1986	1987
Basic research	1,208,229	1,202,094	1,388,337
Applied research	638,916	678,003	887,614
Total	1,847,145	1,880,097	2,275,951

* The years shown are fiscal years
Data: U.S. Council Report (1988)
New Developments in Biotechnology-4, U.S. Investment

As shown above, the government promotes and supports basic research, and the research organizations or universities implement it. In contrast, application fields or R&D aimed at commercialization is carried out under private leadership centered on cooperation between industry and universities. Development programs resulting from direct governmental support are hardly seen in this private R&D.

(2) Japan's Trends

Table 4-2-8 shows Japan's research expenditures in the life sciences.

During 1987, companies' share of research expenditures was 48.3%; research organizations, 14.4%; universities, 37.3%. When compared with the shares by sector of all research expenditures (companies, 72.0%; research organizations, 14.6%; universities, 13.4%), universities' large share of research expenditures in the

Table 4-2-8 Research Expenditures in the Life Sciences

	Companies, etc.	Research organizations	Universities, etc.	Total amount
1981	255,816	54,040	194,037	503,893
1987	483,820	143,678	374,005	1,001,503

* Company data for 1987 involves companies with al least 100 million yen in capital

Data: "Investigative Report of Research in the Life Sciences" Management and Coordination Agency, Statistics Bureau

life sciences stands out; it also correlates with universities' large share of Japan's research paper announcements. We already mentioned that cooperation between industry and universities is main form of U.S. biotechnology R&D systems, but in Japan, national and public universities mostly carry out the research in the life sciences. Also, there is also the tendency for Japan not to halt industrial cooperation; cooperation between the industry and universities is not as prevalent as in the U.S.

Nevertheless, in Japan, too, there is steady movement in the joint research between industry and universities, the origin of which was the joint research system linking national universities with private enterprises that was inaugurated in 1983. In this system, researchers from national and other universities moved forward under that identification in joint research with outside researchers. As a result, it contributed to Japan's independent and creative R&D and started out with the goal of rounding out and strengthening scientific research in universities. During FY 1988 research was implemented with 700 private and other researchers participating in a total of 583 research themes, among which 64 joint research efforts were in the field of biotechnology (Table 4-2-9).

The importance of basic research is especially recognized in the field of biotechnology, and there are great expectations for the basic R&D taking place in universities. As seen in the U.S. example, the perfection of joint research systems is thought to be one means.

Table 4-2-9 Joint Research in Biotechnology by Industry and Universities

	1983	1984	1985	1986	1987	1988
Number of projects	7	21	31	48	70	64
Percentage	12.5	13.1	14.4	17.6	17.7	11.0

* The years shown are fiscal years
* Percentage: Number of biotechnology projects / Total number of projects x 100

Data: "Joint Research with the Private and Other Sectors" state of implementation, Ministry of Education

(3) Europe's Trends

A great difference between biotechnology R&D in the U.S. and in Europe is the government's involvement. In the U.S., as mentioned previously, development programs based on direct government support are hardly seen. But in West Germany, the U.K., and France, the governments are drawing up comprehensive national assistance programs. For example, the West German Federal Research and Technology Agency is creating the Biotechnology R&D Program; the British Ministry of Trade and Industry is at the center of the Biotechnology Aid Program; the French Ministry of Research and Technology is creating the Biotechnology Development Promotion Program. In addition to governmental support, these countries are carrying out R&D within single-bodied government-private systems.

One of the main British programs is the LINK program, at the center of which is the Ministry of Trade and Industry and the Ministry of Education and Science (Table 4-2-10). A joint research assistance program that was announced in 1986, the LINK program aims at carrying out joint industry-university research that is consistent from the early stages of a technology, and achieving more efficiency in R&D. It is a system in which research projects are freely proposed by both the private and government sides; the government defrays 50% of the total costs of projects that are adopted, and business provides the rest. Since the first five projects were decided in 1988, the government is said to be planning to provide a total of 420 million pounds in assistance until 1993.

In France, on the other hand, since the report entitled "The Life Sciences and Society" was submitted to the government in 1980, biotechnology has been promoted at the national level under the cooperation of research organizations and industry. Of France's 2.92200 billion francs in biotechnology research expenditures in 1987, the government provided 2.8 billion francs, and private enterprises, 122.00 million francs. It is apparent that the nation is taking the initiative in promoting R&D.

We cannot overlook the EC's R&D programs in the R&D trends of each of the European countries. The BAP program is one of the EC's biotechnology-related R&D programs (Table 4-2-10). A five-year program that was started in 1985, it emphasizes equipping the base for supporting Europe's biotechnology, and basic biotechnology research and educational training.

Table 4-2-10 Europe's Joint R&D Programs

	BAP[1] Program	LINK Program (U.K.)
	To promote, with a mid- to long-term viewpoint, R&D relating to pre-competition-stage themes in the required fields of Europe's industry and agriculture. Goals are: 1) Equipping the infrastructural foundation used to support Europe's biotechnology, 2) biotechnology research that can be applied in industry and agriculture and education/training.	To promote joint research in which British industry and universities cooperate in order to guide strategic technologies, products, and services towards marketization. At the same time it also aims at increasing industry's R&D investments, exploiting resources and reforming consciousness through industry-university cooperation, and the development of technology that goes beyond the walls of the industrial and academic worlds.
Period	1985 - 1989	1986 -
# of projects	260 projects (1989)	21 projects (1989)
Budget scale	7,500 ECU	402 million pounds
Research domains	· Equipping the infrastructural base Bio-information, collecting biological varieties and materials · Basic biotechnology Enzyme engineering, genetic engineering, physiology and genetics of varieties important to industry and agriculture	· Electronics · Biotechnology · Advanced materials · Advanced manufacturing technology
Remarks	The BAP program was interchanged with the previous BEP[2] program. After 1990 it will be continued in the four-year BRIDGE[3] program.	70 private industries, 26 universities, and 5 research organizations are participating.

* 1 The Biotechnology Action Programme
* 2 Biomolecular Engineering Programme
* 3 Biotechnology Research for Innovation, Development and Growht in Europe

Each of the European countries are basically carrying out government-led R&D in which the government and the private sector have become a single body.

(4) International Cooperation in R&D

As is clear from the discussion above, of the fields in the life sciences, the rapid evolution of biotechnology and genetic engineering, at the nucleus of which is recombinant DNA technology, was a development that was accelerated most of all by the leadership of the U.S.

After building upon later trends, we consolidate our information:

1) The development of biotechnology was led by the U.S., and it expanded in one stroke into global-scale R&D development.

We can say that this U.S. leadership had been based on the abundance of research personnel and research stock in molecular biology and other fields; and furthermore on the uniqueness of the U.S.--the genesis of corporate vigor resulting from bio-venture enterprises.

As far as looking at the numbers of research papers, the U.S. is followed by Japan and France, then West Germany and the U.K. Shall we say that the current state of affairs is one in which the stronpoints are scattered among Japan, the U.S., and Europe.

2) Attention is also drawn to the fact that the U.S. played an active role as a leader with respect to research content and concrete cooperation with Japan and Europe.

At that time, the numerous bio-venture enterprises of the U.S. played a crucial role. These bio-venture enterprises also served to link basic research of the U.S. with Japanese industry.

For example, as illustrated in Table 4-2-11, international cooperation among U.S. bio-venture enterprises and Japanese firms grew rapidly around 1980. With this as a turning point, R&D in Japan's companies and universities was further facilitated.

3) Now, R&D in biotechnology and the life sciences is progressing concurrently in the world.

In Europe, however, government-policy-type support for cooperation between the government and private sector is intensifying much more than in Japan and the U.S., so

attention is focused on what form those effects will take in international cooperation.

Currently, anti-cancer strategies and AIDS counter-measures are great themes that the developed countries have in common. Competition and cooperation at the scientific and industrial levels will probably expand further.

Table 4-2-11 Examples of International Cooperation in Biotechnology

Technology	U.S. Firms	Japanese Enterprises
γINF	Biogen	Shionogi
	Genentech	Toray and Dai-ichi Seiyaku
	G. D. Searle	Meiji Seiyaku
IL-2	Biogen	Shionogi
	Genex	Yoshitomi Pharmaceutical Industries
Serum-albumin	Genentech	Mitsubishi Chemical Industries
	Genex	The Green Cross Corporation
Hepatitis-B vaccine	Biogen	The Green Cross Corporation
	Genentech	Mitsubishi Chemical Industries
TPA	Genentech	Kyowa Hakko Kogyo and Mitsubishi Chemical Industries
	Biogen	
	Genex	Fujisawa Pharmaceutical Company
	Integrated Genetics	Yamanouchi Pharmaceutical Company
EPO	A M Gen	Toyobo
	Genetics Institute	Suntory
	Integrated Genetics	
TNF	Biogen	Fujisawa Pharmaceutical Company
	Genentech	Asahikasei
	City of Hope	

Data: Items taken from NIKKEI BIOTECH and other newspapers

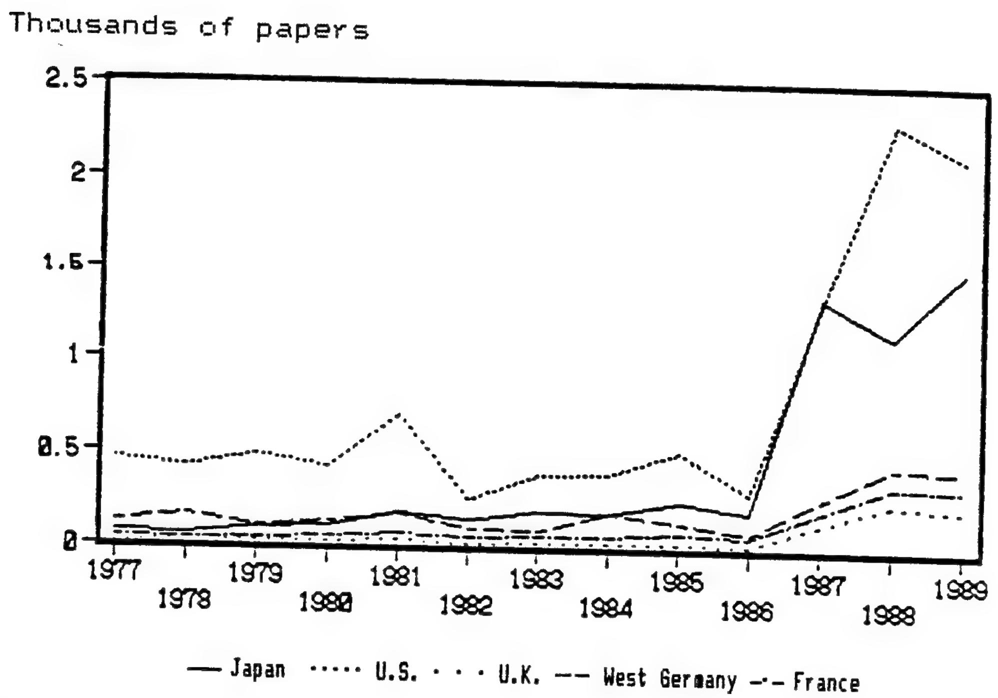
4-3 Changes Seen in the Field of Superconductors

4-3-1 Changes Seen in the Numbers of Research Papers

The emergence of high-temperature oxide superconductors was overly dramatic. From superconductor theory to applications as materials, the impact it brought about only shook the existing knowledge and hypotheses from their foundations.

This is expressed in the changes in the numbers of research papers on superconductors, shown in Figure 4-3-1.

Figure 4-3-1 Changes in the Numbers of Research Papers in the Field of Superconductors



Note: See #1 for data sources

It is very clear that the sudden change after the end of 1986 was a total reversal in the number of research papers, which up until that point involved alloy superconductors.

The following is a look at details about the early stage:

April 1986	IBM Cherry Hill Laboratory, contribution to a journal by Drs. Bedsorts and Mueller to announce a research paper
September 1986	Publication
November 1986	Tokyo University, Professor Tanaka, discovery of 23-K superconductor, newspaper announcement
December 1986	Tokyo University, Professor Fueki, announcement of a strontium substitution product
February 1987	University of Houston, Professor Chu, yttrium high-temperature superconductors announced

If the first phase of high-temperature oxide superconductors, which are made of yttrium and other rare earth oxides, was from the end of 1986 to 1987, then the Bi-Sr-Ca-Cu oxides, which were published in January 1988 by Director Maeda of the Science and Technology Agency's National Research Institute for Metals, indicate the beginning of the second phase.

Table 4-3-1 below brings to the surface this great change and the synchronous structure of superconductor research promotion by Japan and the U.S.

The shares in research papers changed in 1987 and 1989 as shown in Table 4-3-1. In any event, Japan and the U.S. accounted for overwhelming shares and are becoming the world's superconductor-research centers.

Table 4-3-1 Changes in the Shares of the Numbers of Research Papers in the Field of Superconductors

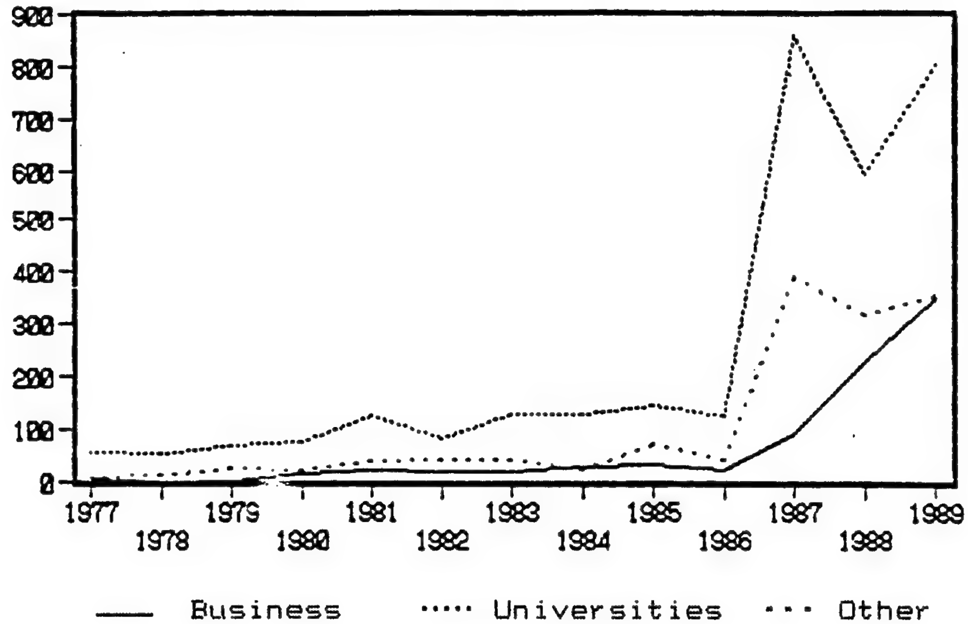
	Japan	U.S.	U.K.	West Germany	France
1987	41.0	40.5	4.2	8.1	6.2
1989	32.8	46.0	4.8	9.3	7.1

Data: Same source as Figure 4-3-1

Figures 4-3-2 and 4-3-3 show the numbers of research paper publications by sector for Japan and the U.S., respectively.

From the comparisons of Japan and the U.S. it is clear that in both countries' universities and national research organizations publish the most papers, followed by businesses, whose R&D is rapidly advancing.

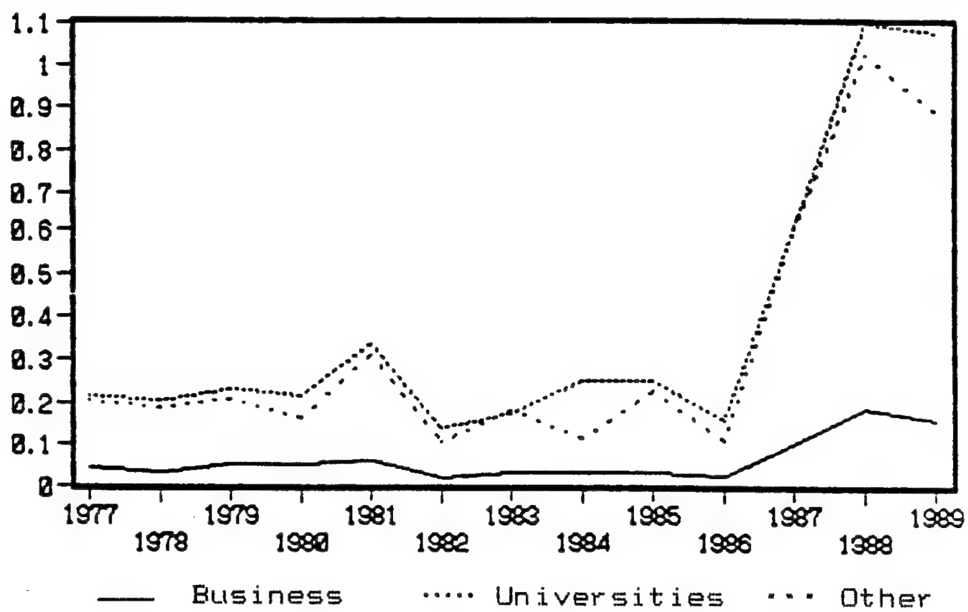
Figure 4-3-2 Number of Japan's Research Papers on Superconductors, By Sector (Papers)



Data: Same source as Figure 4-3-1

Figure 4-3-3 Number of U.S. Research Papers on Superconductors, By Sector (Papers)

Unit: Thousands of papers



Data: Same source as Figure 4-3-1

Also, from Figures 4-3-4 and 4-3-5, which show the changes by country in the numbers of research papers published by universities and businesses, respectively, the following trends in recent years are evident.

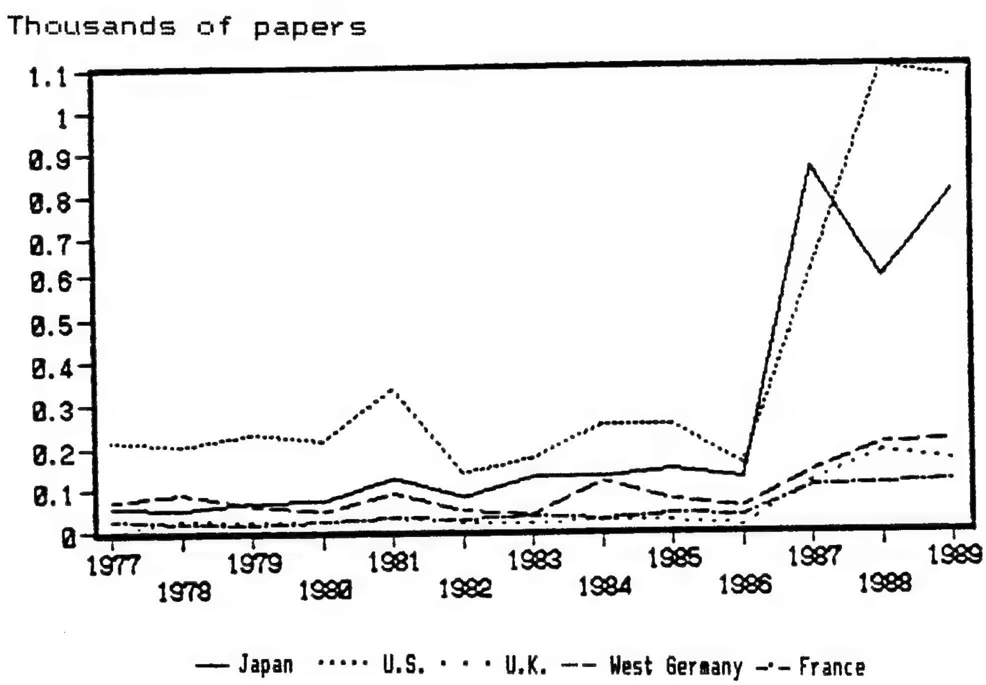
1) With Japan and the U.S. showing rapid increases in the numbers of research papers, universities and business are both playing leadership roles. The trends is both Japan and the U.S. are also synchronous. This implies the coexistence of keen competition and cooperation.

2) Japan tends to show a more rapid increase in the number of research papers than the U.S. This suggests that Japan's grappling with R&D is quick and highly concentrated.

3) In Japan, the number of research papers from businesses has tended to increase since 1987, but in the U.S. both universities and businesses published less papers during 1989.

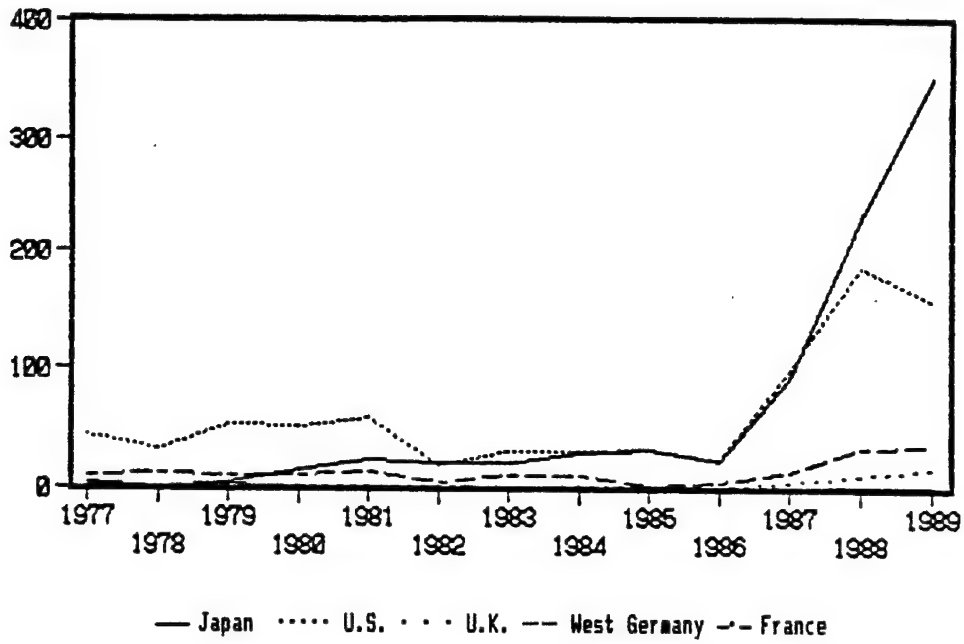
We shall say that this indicates the differences in Japanese and U.S. trends with respect to how they deal with research and the release of those results.

Figure 4-3-4 Numbers of Universities' Research Papers on Superconductors



Note: See Figure 4-3-1 for data sources

Figure 4-3-5 Numbers of Research Papers on Superconductors in the Business Sector (Papers)



Note: See Figure 4-3-1 for data sources

4-3-2 Changes Seen in Patents

In connection with superconducting materials, which are also said to symbolize the new materials, the leading roles played by Japan and the U.S. are directly revealed in the aspect of patents, too. The relative positions of Japan and the U.S. as the world's research centers is becoming obvious.

Although there is a timelag after a research paper is published, patent applications pertaining to high-temperature oxide superconductors have been released continuously since July 1988, even in Japan.

If we arrange the data according to the year in which the patent was applied for, we can present the changes during the early phase, when yttrium superconductors emerged, as Figure 4-3-6.

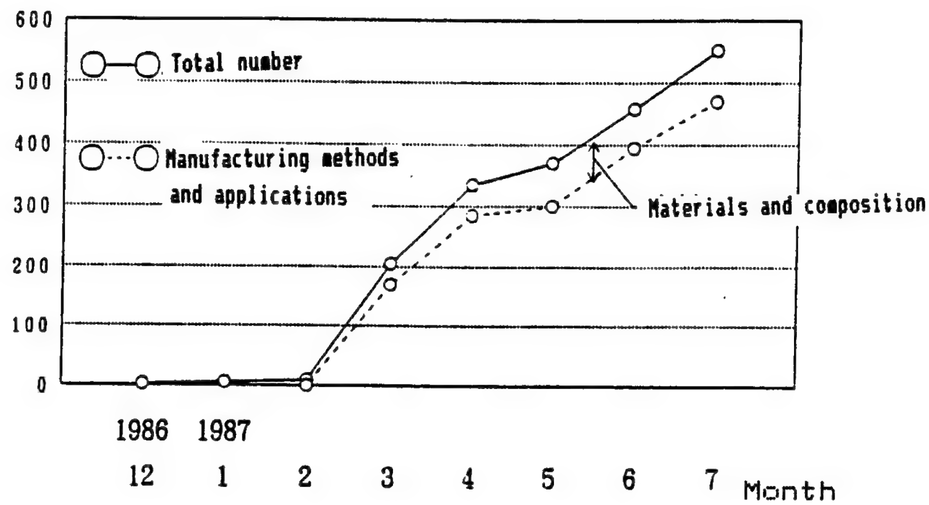
It shows an increase in the number of patent applications so sudden that it was astounding. Furthermore, what we would like you to pay attention to is that in March 1987 (i.e., just a few months after oxide superconductors were announced at the end of 1986) 50% of all patent applications were for manufacturing methods; when applications are included, actually 85% of the

patents that were applied for pertained to manufacturing and application technology.

Here, Japanese businesses' concentration of energy on practical-use development of superconducting materials is conspicuously revealed.

Figure 4-3-6 Japan's Patent Applications for High-Temperature Oxide Superconductors: Early Stage Trends

(Patent applications)



The same kind of situation is also evident in the case of bismuth superconductors during the early stage after 1988.

Immediately after the announcement in January 1988 by Director Maeda of the Science and Technology Agency's National Research Institute for Metals, patent applications from Japanese businesses increased rapidly, and the development of manufacturing methods and application technology progressed. There are some eye-openers in that vigor, which may also be described as explosive, and the speed with which businesses got involved.

Tables 4-3-2 and 4-3-3 show the early-stage trends in patent applications for yttrium and bismuth superconducting materials. As is clear from these tables, Japanese businesses dealt with the situation quickly; moreover, they applied for patents that were content-wise replete; and there were many businesses doing so. Meanwhile, as far as patents go, the overall vitality of U.S. businesses has been poor, and in future technology development its lag behind Japan is expected.

Table 4-3-2 Early Stage Trends in Patent Applications for Lanthanum and Yttrium Oxide Superconductors

Application Date (Priority Date)	Applicant (Discoverer)	Release and other data	Composition
1986. 12. 22	Kazuo Fueki (Tokyo Univ.)	*Tokkai* 63-260853 (10/27/88)	Lu-(Sr, Cs)-Cu-O_x
1988. 1. 8 (1987. 1. 9)	AT&T (Batlogg et al.)	*Tokkai* 63-222068 (9/14/88)	La-(Ba, Sr, Ca)-Cu-O_x
1987. 11. 9 (1987. 1. 12)	Univ. of Houston (Chu et al.)	WO 88/05092 (7/14/88)	(La, Y)-(Ba, Sr, Ca)-(Cu, Bi, Ta, Ti)O_x
1987. 1. 17	Tokyo Univ. (Akiji Tanaka et al.)	*Tokkai* 63-176353 (7/20/88)	La-Ba-Cu-O_x
1988. 1. 20 (1987. 1. 23)	IBM (Muller et al.)	*Tokkai* 63-190712 (8/8/88)	RE-(Ba, Sr, Ca)-Cu-O_x
1987. 1. 30	Hitachi, Ltd. (Haruo Hasegawa et al.)	*Tokkai* 63-190713 (8/8/88)	(La, Y)-(Ba, Sr, Ca)-Cu-O_x
1987. 3. 12	NTT (Tomoaki Yamada et al.)	*Tokkai* 63-225525 (9/20/88)	Md-Ba-Cu-O_x
1987. 3. 12	NTT (Tomoaki Yamada et al.)	*Tokkai* 63-225526 (9/20/88)	Tm-Ba-Cu-O_x
1987. 3. 12	NTT (Tomoaki Yamada et al.)	*Tokkai* 63-225527 (9/20/88)	Lu-Ba-Cu-O_x
1987. 3. 13	Toshiba Corp. (Akatsuki Murase et al.)	*Tokkai* 63-225524 (9/20/88)	La-Ba-Cu-O_x
1987. 3. 13	Toa Nenryo Kogyo K.K. (Satoru Sakurada et al.)	*Tokkai* 63-225529 (9/20/88)	Lanthanum-alkali earths -(Fe, Co, Ni)-Cu-O_x
1987. 3. 13	Tokyo Univ. (Shinobu Mizukami)	*Tokkai* 63-225530 (9/20/88)	Y-Ba-Cu-O_x
1987. 3. 13	NTT (Shigetsura Tsurumi et al.)	*Tokkai* 63-225531 (9/20/88)	(La, Y)-(Ba, Ca)-Cu-O_x
1987. 3. 13	Tokyo Univ. (Akiji Tanaka et al.)	*Tokkai* 63-225272 (9/20/88)	Y-(Ba, Sr, Ca)-Cu-O_x

1987. 3. 13	NTT (Tomoaki Yamada et al.)	*Tokkai* 63-225273 (9/20/88)	Bi-Ba-Cu-O_x
1987. 2. 5	Sumitomo Electric Industries, Ltd. (Hideo Itozaki et al.)	*Tokkai* 63-193410 (8/10/88)	La-(Ba, Sr)-Cu-O_x
1987. 2. 9	Sumitomo Electric Industries, Ltd. (Masaaki Tobita)	*Tokkai* 63-195116 (8/12/88)	La-alkali earths-Cu-O_x
1987. 2. 17	Sumitomo Electric Industries, Ltd. (Tatsuaki Ohkura)	*Tokkai* 63-200506 (8/18/88)	Thin-film coil fabrication

Table 4-3-3 Early Stage Trends in Patent Applications for Bismuth and Thallium Superconductors

Application Date (Priority Date)	Applicant (Discoverer)	Release and other data	
1988. 1. 20	National Research Institute for Metals director (Hiroshi Maeda et al.)	*Tokkai Heisei* 1 -188456	Bi-Sr-Ca-Cu-0_x
1989. 1. 13 (1988. 1. 15)	Univ. of Arkansas (A.M. Aaron et al.)	*Tokkai Heisei* 1 -219007	Tl-ⅡA-ⅠB-6A-0_x
1988. 1. 26	Semiconductor Energy Institute (Iwahei Yamazaki)	*Tokkai Heisei* 1 -192758 -192759	(Bi, Sb, As, P)-(Ba,Sr,Ca,Mg)-Cu-0_x
1988. 2. 5	Matsushita Electric Industrial Co. (Tomokazu Harimiya et al.)	*Tokkai Heisei* 1 -201024 -201025 -201027	Bi-ⅡA-Cu-0_x
1989. 2. 3 (1988. 2. 5)	Hekst (West Germany) (Schoenering et al.)	*Tokkai Heisei* 1 -226737	Bi-(Sr, Ca)-Cu-0_x
1988. 2. 8 (1988. 2. 8)	Dupont (Straight et al.)	WO 89/07087 (1989. 8. 10)	Bi-Sr-Ca-Cu-0_x
1989. 2. 10 (1988. 2. 12)	AT&T (Carver et al.)	*Tokkai Heisei* 1 -242421	Pb-Bi-Sr-Ca-Cu-0_x
1988. 2. 15	Seiko Epson (Eiji Natori)	*Tokkai Heisei* 1 -208325	Tl-(Sr, Ca, Ba)-Cu-0_x
1988. 2. 16	Matsushita Electric Industrial Co. (Junichiro Kawashima et al.)	*Tokkai Heisei* 1 -208329	Bi-Sr-Ca-Cu-0_x
1988. 2. 25	Sumitomo Electric Industries, Ltd. (Hideo Itozaki et al.)	*Tokkai Heisei* 1 -286921	Tl-Ca-Ba-Cu-0_x
1988. 3. 23	Institute for Production and Development Science (Toshio Takata et al.)	*Tokkai Heisei* 1 -242419	Pb-Bi-Sr-Ca-Cu-0_x

4-3-3 What Caused the Changes, and International Competition and Cooperation

Superconducting materials are expected to become the extremely important seeds for technological innovation in the 21st century.

Because of this, the emergence of high-temperature superconductive yttrium and bismuth oxides since 1986 has had a great impact. These were epoch-making discoveries that will lead to a new era in the development of new materials.

As is clear from the state of affairs in patents and research papers that was discussed previously, the following points with respect to superconductor R&D have come to light. We can say that these points are indicative of the global changes in the overall new materials R&D situation and the reasons thereof.

1) Japan and the U.S. are acquiring global leadership positions. It has become clear that Japan and the U.S. have formed two poles as R&D centers.

   Furthermore, the synchronicity in R&D, occurrences that are a manifestation of keen Japanese-U.S., and also worldwide, competition, is becoming obvious.

2) Nevertheless, there are some aspects that we should pay attention to: the great vigor in the R&D of the Japanese business sector, and the speed at which research in superconductors is evolving towards manufacturing technology and applications.

   Because ceramics technology is a basis, too, perhaps we should also not overlook the aspect that superconductor R&D is suitable for the Japanese business sector's involvement.

3) Conversely, we get a strong impression that overall U.S. business vitality is waning.

   We can think of this trend as a reflection of U.S. business' judgment that the commercialization of superconductors is difficult in the short term. We can also think of it as pointing to the unique side of U.S. business that orients itself towards development with short-term prospects.

This kind of vigorous R&D in superconductors, which can be seen in research papers and patents, has become further accelerated in Japan by government policy measures. Table 4-3-4 exemplifies these support policies.

Table 4-3-4 Japan's Policies for Promoting Superconductor R&D

1987 "On Basic Policies for Promoting Superconductor R&D"
Council for Science and Technology

1988 Science and Technology Agency's superconductor research
- Multicore Project launched

Ministry of Education's scientific research support funds
- Elucidating the mechanisms of superconductivity
- Research on high-temperature superconductors

MITI's Next-Generation Base Technology R&D
- Superconductor technology and superconducting devices

Research and Development Corporation of Japan
- Superconductor high-tech consortium

Anxious about these kinds of trends in Japan, the U.S. moved towards the formation of a cooperative government-private system for the development of superconductors, but so far there have been no visible results.

Participation by the U.S. business sector in the field of superconductors is not very noticeable. Perhaps this is indicative of the dwindling vitality of that sector. Perhaps it is the one side of the coin where there is not that much interest in superconductors as a business. Preferably, perhaps the U.S. business sector thinks that the attitude of Japanese business is unique. That is, the tendency for concentration on objectives and the predisposition towards excessive competition that is seen in Japanese businesses' R&D, and the height of the interest in manufacturing and applications technology, is unique.

Nevertheless, we can see from the co-authors of research papers and other collaborators that joint research by Japanese and U.S. universities and businesses, and also Japan-U.S. cooperation, is moving out of early-stage R&D. As can be seen in Table 4-3-5, there are some noteworthy developments in the evolution of international cooperation at the scientific-research level.

As far as the present state of affairs, though, Japan's leadership in the development of superconducting materials is obvious. We cannot deny that Japan is shouldering a major role that will lead the world's future R&D.

From that standpoint, we must also take into consideration the R&D vitality of Japan's business sector.

Table 4-3-5 Joint International Research Seen in Co-Authored Research Papers (Japan 1987-88)

Japanese Research Organization	Foreign Research Organization
University of Tokyo	Brookhaven National Lab. USA Exxon Research & Engineering Co. USA
Tokyo Institute of Technology Univ. of Tokyo	Univ. British Columbia CAN Lockheed Palo Alto Research Lab. USA
Tohoku University	Solar Energy Research Institute Co. USA
Toyama University	Univ. Antwerp BEL SCK/CEN BEL State Univ. Leiden NLD
University of Tokyo	Brookhaven National Lab. USA AT&T Bell Lab. USA ETH-Honggerberg CHE
University of Tokyo Tokyo Institute of Technology	Univ. British Columbia CAN
University of Tokyo Tokyo Institute of Technology Ochanomizu University	Univ. British Columbia CAN TRIUMF BC CAN Univ. Saskatchewan CAN
Tohoku University	Solar Energy Research Institute Co. USA Univ. Paris-Sud FRA Univ. Degli Studi di Roma "La Sapienza" ITA Instituto Nationale di Fisica Nucleare ITA
Tohoku University Okazaki Molecular Science Lab.	Massachusetts Institute of Technology USA Brookhaven National Lab. USA
Tohoku University NTT	Iowa State Univ. USA Brookhaven National Lab. USA Exxon Research & Engineering Co. USA
Kagoshima University	Lausanne Univ. CHE
Waseda University	Tata Institute of Fundamental Research IND
NTT	Massachusetts Institute of Technology USA Brookhaven National Lab. USA
NEC	Brookhaven National Lab. USA
Okazaki Molecular Science Lab.	Brookhaven National Lab. USA Massachusetts Institute of Technology USA

Data: Research and Development Corporation of Japan's databook collection

4-4 Changes Seen in Aerospace Fields

As a field that initiates technologies, aerospace technology always continues to extend a 'technology spillover' effect on other fields, and it has come to be recognized as a motive force that builds up today's leading-edge technologies.

For that reason countries throughout the world have come to actively support the development of aerospace technology and long-term, large-scale aerospace projects. Up to this point the U.S. has continued to lead the world in the development of advanced technology. That internal structure, however, is realizing various changes.

4-4-1 The Aircraft Field: Circumstances and the Present

1. U.S. Leadership (1945 - 1960's)

The U.S. led the world in aircraft technology after the war. It invited German engineers and then put them to work in jet and rocket R&D, thereby attaining straight-out rapid progress. Furthermore, it leads the world in civilian aircraft after having made the best use of the large-bomber technology that it had accumulated during the war, and then immediately developing large passenger planes.

There was also post-war U.S.'s plunge into the era of the Cold War with the Soviets. As a result, military aircraft R&D, which was guided by the Army, Navy, and Air Force, became prosperous.

Missiles (rockets), which developed mainly in Germany during World War II, also came to show astounding growth after the war. The demand for fighter planes and bombers, which up until then had accounted for 80% of expenditures for military aircraft, fell; enthusiasm for R&D also dropped. In 1958 missile sales rose to 25% of the aerospace industry's total sales. Missiles' strongpoints were that 100% of the orders were from the government, and their development costs were higher than those for airplanes.

At the start of the 1960's, the conversion of military-use super-large transport plane technology caused the aerospace industry to develop the third generation of passenger planes. Boeing had to complete the B747; Mcdonnell Douglas, the DC10; and Lockheed, the Tristar. NASA was also cooperating in the development that resulted from those research efforts. After 1965, however, changes took place: the use of electronics in aircraft progressed due to the increasing sophistication of military aircraft, and missile equipment and mobility was emphasized; airframe technology in military and commercial aircraft had less and less

in common, and both kinds of aircraft assumed forms in which R&D was pushed forward in independent manners.

On the other hand, because their land had become a battleground, the aircraft industries of European countries were dealt an annihilating blow. One of those countries that strove to rebuild immediately after the war was the U.K.

The U.K. made the most out of technology that had advanced before the war and was developing more different kinds of jets than the U.S. immediately after the war. In 1957 it put into service the world's first passenger jet, the Dehavilland-made Comet.

Nevertheless, aircraft technology that plunged into the era of jets was different from pre-war aircraft technology: in one stroke it became sophisticated and more complex; as a result, R&D and production started to require enormous amounts of capital and advanced technological strength. Despite its small land area and a shared domestic market that was naturally small, the U.K., with its tradition of free competition, had a flood of small-scale aircraft manufacturers. These manufacturers suffered defeat and then were gradually wiped out in the competition with U.S. aircraft manufacturers, who had already been undergoing tremendous expansion. Consequently, the overall strength of the British aircraft industry weakened.

France, who had 200,000 people [in the aircraft industry] during the peak before the war, sustained an even more destructive blow than did the U.K. because it had been occupied by the Germans from early on in the Second World War.

Though France lagged behind the U.K. in technology, it developed the Caravelle passenger plane in 1959 and then the Mirage-3 fighter plane in 1961. Like the U.K. it was later defeated by the U.S. in civil aircraft. In military aircraft, however, the Mirage flourished, and many were produced for France itself and for exports.

Germany, during the war, had showed spectacular expansion and had developed, one after another, epoch-making aircraft and missiles. After the war, as in Japan, aircraft R&D and production was absolutely prohibited by the occupational policies of the Allied forces. Thus Germany vanished from the world's front line.

Nevertheless, in 1955 it was permitted to resume. The Ministry of Defense worked towards rebuilding the aircraft industry with a five-year plan that was based on financial support from the federal and prefectural governments.

Figure 4-4-1 Aircraft Developments and Future Prospects

Generation	Representative Application Aircraft	Year	Airframe Technology	Engine Technology
Era of higher speed and diversification (era of space + aircraft)				
Manned space shuttle	SP			Air-bridging
	HST	2000	C/C materials	engine
Second-generation SST	SST		Powder metallurgy	
V/STOL	VSTOL		AI control	
	FSX		FRM (fiber-reinforced metal)	Variable-cycle engine
			laminar flow	used in the SST
	B777	1990	Primary structure	Super-high bypass
			composite materials	engine
Super-energy-efficient craft	MD91			
Soviet's shuttle success	A340		SAS (stability augmentation system)	
In quest of economy				
	A320		High aspect ratio	V2500
STOL aircraft (Asuka)	B747-400		High tensile aluminum	
Space shuttle success (U.S.)	B-1B			
Fourth-generation jet	B767	1980	Secondary structure	Third-generation turbofan
	F-16		composite materials	
	F-15		CRT displays	
The era of high-volume tranport				
Third-generation jet	P-14		Super-critical wings	
	C-1		Digital automatic control	Second-generation turbofan
	B-747			
First-generation SST	Concorde	1970		FJR-710 development
Mach-3 flight (SR-71)	PS-1			Olympus 593 (SST engine)
Second-generation jet	B721		J-NAV	
	MU-2			
The era of jet aircraft				
	YS-11	1960	Multiple-slot flap	Low-bypass turbofan
First-generation jet	B707		Fowler flap	(cooled turbine)
	OC-B			
The age of propeller planes				
Supersonic speed breakthrough				Supersonic turbojet
(X1)		1950	Swept-back wing	Turboprop
	Comet			Turbojet
V-2 rocket development	Highcount			
(Germany)				
		WW II		
		1940		
			Pressurized cabins	Non-gas turbine
				supercharger

Advent of civil tranport planes				
	OB-3			
	B247			
		1930	Flap (split)	
	<u>Kokenki</u>			
			Retractable landing gear	Variable-pitch propeller
			Metal planes	
		1920	Monoplane	Supercharged engine
	Junker's J-1			Star-shaped engine
Military use			Cantilever wing	
		WW I		
	Fokker			
		1910		
Mail transport				
	Sikorsky			
			Biplane	Gasoline engine
			First flight by the Wright brothers (17 December 1903)	
		1900		
			Hot-air balloons, airships, glider planes	

* The aircraft/engines in whose development Japan participated are underlined

Data: "Kikai Shinko" (Promoting Mechanics) February 1990

Like West Germany, Japan's aircraft industry, whose employees numbered 1,000,000 in peak times during the war, also disappeared as a result of the aircraft-prohibition occupational policies that were adopted. But after the "aircraft ban was lifted" in March 1952, the companies that had been developing and producing aircraft before the war all at once branched out.

At first, Japan introduced fighter plane and other advanced technology from the U.S. and engaged in licensed production.

Nevertheless, in development requiring advanced technology, there was too great a disparity between Japan's technology and that of world, and much of its R&D did not make it as far as practical applications.

2. Europe's Rise and Joint Development (1970 -)

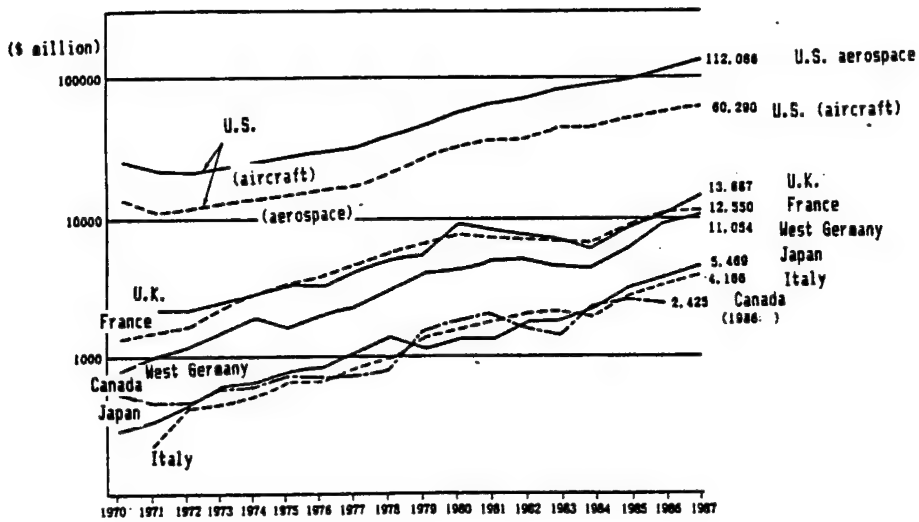
With the conclusion of the Viet Nam war, and, too, the sudden jump in raw material costs and personnel expenses due to the oil crises, U.S. defense expenditures decreased during the early 1970's. Furthermore, because President Carter, who emerged in 1974, put the brakes on R&D expenditures for military aircraft that were costing increasingly enormous sums of money, new aircraft R&D slowed down. However, new aircraft development became active again after President Reagan, who assumed office in 1981, pushed for increased defense expenditures.

Nevertheless, with the advances in semiconductors, opto-electronics, lasers, and other such technologies, the cost of developing new aircraft grew to astonishingly enormous sums--prices in the 100's of billions of yen that were higher than the value of the pure assets of the companies developing the aircraft. Then fighter planes started to cost more than 10 billion yen apiece. For this reason, the total number of planes produced decreased in comparison to previous production volumes; further, starting the development of a new type of plane became more difficult.

NASA's role in new aircraft development underwent a great change as a consequence of the sudden jump in oil prices due to the oil crisis in October 1973 and the fact that the instability of the supply from the Middle East was becoming an issue. In 1975 the Aircraft Energy Efficiency (ACCE) Program was decided upon, and the following research efforts commenced:

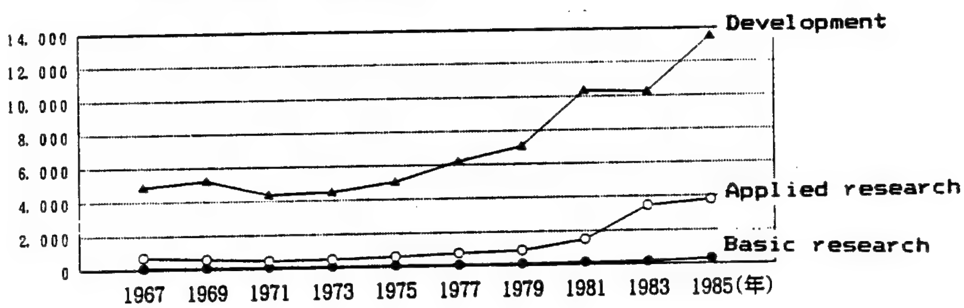
1) achieving energy efficiency by making engines more efficient and by improving airframes;
2) advanced turboprop engines, the objective of which is energy efficiency;
3) liquid hyrdogen transport planes, et al.

Figure 4-4-2 Each Countries' Aerospace Industry's Sales Volumes (converted to U.S. dollars)



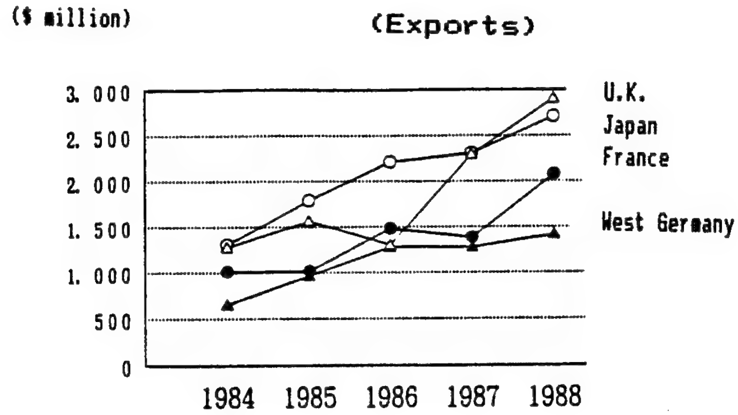
Data: Society of Japanese Aerospace Companies, Inc.

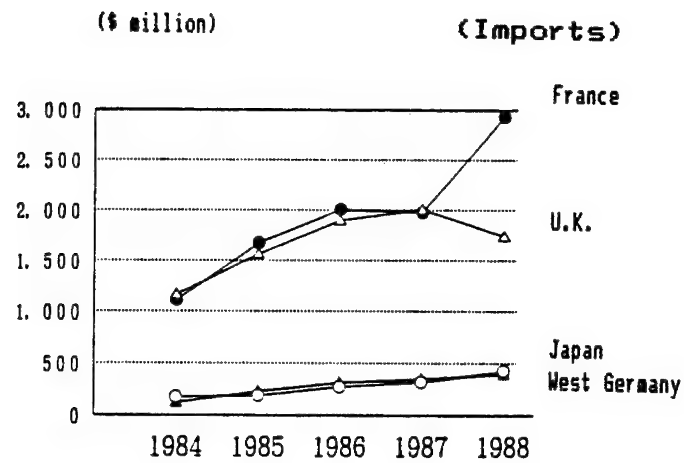
Figure 4-4-3 R&D Expenditures in the U.S. Aerospace Industry (millions of dollars)



Data: NSF

Figure 4-4-4 U.S. Trade in Aerospace Products ($ millions)





Data: U.S.DOC International Trade Administration

In order to achieve these objectives, NASA allotted nearly 40% of the research budget that was provided for aviation-related research, which corresponded to about $300 million, to industry and universities for research expenditures.

U.S. policies, which had emphasized performance aboveall (more so than economy) in the promotion of advanced technology development, had to inevitably change. Thus there was a change in the direction of policies towards aircraft development with the stress on economy and energy efficiency.

New R&D in the 1980's featured a return to grappling with the challenge of SST (supersonic transport plane) R&D, which the U.S. had once abandoned in 1971. Furthermore, progress was made in research for the space plane, a successor to the space shuttle

activities. These R&D expenditures require trillions of yen. Because even the gigantic U.S. cannot cover all of costs alone, joint development that includes Europe and Japan has been under discussion. In this way, the U.S. is approaching a stage where the "lone runner" system, a form in which it is prominent, must also steadily change.

Meanwhile, in the European countries, joint development starting with military aircraft has become the mainstream since the 1970's.

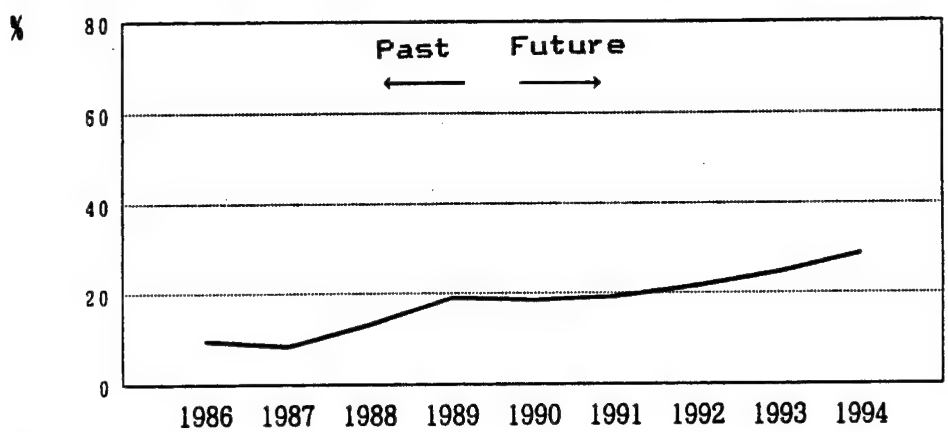
Typical examples are the joint development of a European fighter plane that the U.K., West Germany, Italy, and Spain started; and the Raphal, which was jointly developed by both the U.K. and France. Performance that rivals that of the newest and most powerful aircraft of the U.S. is the objective for both of these projects. Until this point, the European countries did not have sufficient capital and therefore had abandoned the development of new types of aircraft. As a result they fell behind the U.S., but they are now seen as striving to roll back by making a success of these development projects.

A representative example that shows the expansion of European R&D strength since the 1970's can be seen in Airbus Industrie.

In December 1970 France and Germany established Airbus Industrie. In 1980 the U.K. returned and Spain's CASA also joined in.

As shown in Figure 4-4-5, Airbus' share of the world's aircraft production is growing. In some aircraft types, it outpaces McDonnell Douglas of the U.S. With a 35-percent share

Figure 4-4-5 Airbus Industrie's Market Share



Data: From the Airbus company

already secured, it is an influence that will extend further. In 1985 its employees numbered 45,000, which corresponds to one-fourth of all of Europe's aircraft companies' employees; in that respect, it ranks with Boeing.

The development costs of the mammoth aerospace projects that are currently being planned by Europe and the U.S. (e.g., the European fighter plane, the next-generation supersonic transport plane (SST), the space plane that will be the successor to the space shuttle, space development, etc.) are enormous. The sums are becoming so large that a single country--even the U.S.--cannot completely finance these projects. In that alone, a configuration resulting from the cooperative systems of European countries, where R&D expenditures, R&D organizations, and researchers are efficiently employed, will come to play a great role in the future. Awaiting the EC unification that is planned for 1992, it is hypothesized that European joint development systems will be further strengthened. Representative examples are the joint research and space development projects by the European Space Agency (ESA). Furthermore, commercial satellite launches using re-usable Ariane rockets, joint European operations that are centered on France, and other such activities will become all the more vigorous in the future. These kinds of joint operations are regarded as something that will grow into increasingly powerful systems. It is hypothesized that they will strengthen the bond between all the regions of Europe and will grow into one large aerospace industry that will rival that of the U.S.

Meanwhile, Japan's aerospace industry has achieved splendid growth since the 1970's. For example, 80% of its aircraft sales is supported by the growth in defense consumption; sales in 1989 amounted to 800 billion yen, which was seven times that of 1970.

What is attracting attention is the fact that Japan reached a technological level where it has single-handedly developed military-use airframes for two types of supersonic aircraft, the T-2 advanced trainer plane and the F-1 support fighter. In addition, for the first time it developed turbofan engines, which had become the mainstream during the 1970's: the FJR710 (for use in the STOL "Asuka") and the F3 (for use in the T-4 mid-level trainer plane).

In addition to joint international projects with the world's gigantic aerospace firms--the development of the YX/B767 commercial tranpsort plane and the V2500 turbofan engine--the 1980's were distinguished by the fact that Japan developed the parts that it was responsible for. In both projects the Japanese government's financial support amounted to between 50 and 75 percent of the development costs that Japan defrayed.

However, for a long time controversy continued over the development of the FSX, the next support fighter plane of the Japanese Air Self Defense Force. A joint Japanese-U.S. effort that had been decided upon in 1989, the FSX met with considerable opposition from the U.S. Congress that is wary of the outflow of leading-edge aircraft technology from the U.S. to Japan. It was the same situation with the YXX/B777 commercial transport plane, whose joint development with Boeing was decided upon in 1990. What the U.S. is most anxious about is that the technology transferred from the U.S. to Japan as a result of the FSX joint development would be adapted to commercial aircraft, Japan would sooner or later make inroads in the commercial aircraft market and then would plunder the U.S. market. Already there is insistence that Japan should supply the U.S. (General Dynamics) with its technology for forming single-body main wings made of use carbon fiber materials, technology that Japan is said to excel in.

Supported by high technology for the people's livelihood, Japan now ranks tops in the world in some aerospace-related parts, materials, production technology, and the quality of these. We can say that a result of that is those problems that occurred between Japan and the U.S.

The fields that Japan is evaluated highly in are optical, electronics, and composite materials technologies, all of which have developed as technologies for the people's livelihood. In the field of aerospace, as far as the nature of technology goes, high reliability is demanded in component parts. For this reason it is said that 70% of the IC's used in U.S aerospace today are Japanese-made.

Table 4-4-1 Commercial Transport Planes: International Joint Development and Joint Operations

Year Put Into Service	Type Of Aircraft	Number of Seats	Developer (Nationality)
1969	F28	40~65 48~79	Fokker (Netherlands), VFW, MBB (Germany), Short (U.K.)
1974	A300	230~280	Aerospatiale (France), Deutsche Airbus (Germany), Fokker (Netherlands), CASA (Spain), BAe (U.K.)
1974	Mercure	132~165	Dasobreg (France), Airitalia (Italy), CASA (Spain)
1975	VFW614	40	VFW Fokker (Germany,Netherlands)
1976	Concorde	128	BAC (U.K.),Aerospatiale (France)
1982	B767	180~230	Boeing (U.S.),Airitalia (Italy), Civil Aircraft Development Association (Japan)
1983	A310	180~230	Same as the A-300
1992 (Planned)	A340	260~300	Same as the A-300
1993 (Planned)	A330	330	Same as the A-300

Data: Society of Japanese Aerospace Companies, Inc.

Table 4-4-2 International Joint Development of Military Aircraft

First Flight	Type of Aircraft	Developer	(Nationality)
Fixed-Wing Aircraft			
February 1963	Tranzer C160 Transport plane	VFW and MBB Aerospatiale	(West Germany) (France)
September 1968	SEPECAT Jaguar Attack plane/ trainer plane	BAe Dasoburege	(U.K.) (France)
October 1973	TA501 Alphajet Attack plane/ trainer plane	Dorunie Dasoburege	(West Germany) (France)
August 1974	Panavia200 MRCA Tornado Multi-objective tactical plane	BAe MBB and VFW Airitalia	(U.K.) (West Germany) (Italy)
October 1974	SOKO/CNIAR Orao Multi-objective tactical plane	SOKO CNIAR	(Yugoslavia) (Rumania)
May 1984 (Being developed)	AM-X Attack plane	Airitalia Airumaki EMB	(Italy) (Italy) (Brazil)
Rotating-Wing Aircraft			
October 1987 (Being developed) (Being developed)	EH-101 Eurocopter Attack plane	Westland Agstar Aerospatiale MBB	(U.K.) (Italy) (France) (West Germany)

Data: Society of Japanese Aerospace Companies, Inc.

Table 4-4-3 International Joint Development of Engines

Formal Approval (Authorization) Year	Engine	Developer	Type of Aircraft on which Engine is Mounted
1972	Adoa	Rolls-Royce Churubomeka	T-2, F-1 Jaguar
1975	Olympus	Rolls-Royce SNECMA	Concorde
1978	RB-109	Rolls-Royce Turbo Union	Panavia 200
1979	CFM56	General Electric SNECMA	DC-8 B737 A320
1988	V2500	Japan Aircraft Engine Assoc. Pratt & Whitney Rolls-Royce MTU Fiat	A320 YXX/B7J7* MD80 series*
(under development)	EJ200	MTU Fiat Rolls-Royce SENER	Eurofighter

* Type of aircraft on which the engine is planned to be mounted

Data: Society of Japanese Aerospace Companies, Inc.

4-4-2 Technological Developments in the Space Field

1. U.S. Leadership and Those Changes

The success of the Soviet launch of the Sputnik, the world's first artificial satellite, in October 1957 shocked the U.S. and resulted in a total change of the U.S. space development system. The shock was that the Soviets had beaten them to the punch. When the government made the move to recover its position, which in a sense, too, was to recover national prestige, it invested tremendous sums of money in space development. Afterwards, the U.S. and the Soviet Union were rapidly heading towards the path of huge development.

First the U.S. made broad changes to its aerospace development system. In July 1858 NASA was established.

Within a week after its establishment, NASA decided to start the Mercury Program. Over the next two years it mapped out plans for the future, including plans for building up its organization. In February 1960 it drew up a ten-year program that included manned space flights, planetary exploration, and scientific satellite launches. In June 1961 President Kennedy announced the Apollo Program, saying that "by the end of the 1960's we will land a man on the moon." Table 4-4-4 shows a summary of the rockets and spacecraft used in this series of programs.

Table 4-4-4 Content of U.S. Manned Space Flight Programs (1960's)

	Mercury Program 5/61 - 5/63	Gemini Program 3/65 - 11/66	Apollo Program 10/68 - 12/73
Flight results	6 manned flights	2 unmanned flight experiments 10 manned flights	11 manned flights 1 moon landing
Space-craft	1-man capacity (1,357 kg)	2-man capacity (3814 kg)	3-man capacity (28,899 kg) moon-landing craft (15,267 kg)
Rockets	Redstone single-stage Mercury/Atlas single-stage + auxiliary engine (Net wt. 118 tons)	Gemini and Titan two-stage (Net wt. 185 tons)	Saturn 1B two-stage (Net wt. 587 tons) Saturn V three-stage (Net wt. 2893 tons)

Data: THE SPACE SHUTTLE report plan

The greatest problems that NASA faced in making these huge national projects a reality were, of course, in the R&D of advanced S&T, but beyond that there was also the overall coordination and creation of systems that involved administration, economics, national defense, and foreign policy. As a consequence, where NASA would place its orders for machinery and other development had much in common with the Pentagon's procurement system, which came to be diverted for NASA's use, so NASA and the Pentagon built up a system of close cooperation. Furthermore, it was the first time that projects which mobilized a broad range of non-government R&D strength could grow so large. As for the contracts to develop each part of the systems, orders went out in large volumes to primarily aircraft and electronics companies.

Together with the fact that space militarization had escalated, the promotion of commercial activities in outer space, which were getting into stride, was at the center of U.S. space activities during the 1970's. It was the "commercialization of outer space" that was based on the series of technological results achieved during the 1960's. Consequently, what was most often asked about were investigations into what kinds of transport systems and satellite-launching methods were more efficient and more economical, and the development of those systems.

Because of this kind of state of affairs, the development of the Space Shuttle was approved by President Nixon and started in January 1972.

Developed through the joint efforts of NASA, the Pentagon, and aerospace companies, the Space Shuttle Columbia's first flight in April 1981 was a success. During this time the total cost of its development rose to about $10 billion. For about five years, until the Challenger explosion in January 1986, there were 24 succesful flights during which satellites were launched and various experiments were conducted. Then after September 1988 launches were resumed and continued without interruption.

Although the Space Shuttle's economic characteristics were given priority when it was planned, economic problems were once again looked at closely after the Challenger explosion. This was because there were gross overruns of the initial budget estimates; moreover, satellite launches came to a full-scale stop after it became necessary to re-inspect all of the Shuttles.

Up until the explosion, government regulations were strict and there was no profit in private commercial-satellite launches. As a result, disposable-rocket production lines were inevitably discontinued. But the situation changed completely after the disaster: in February 1988 President Reagan announced a new space

policy, and, owing to the removal of regulations on commercial-satellite launches and the simplification of legal procedures, it seemed to instead recommend commercialization.

International cooperation with Western European countries, Japan, the U.S.S.R., and other countries is also become vigorous, and a series of projects are evolving, e.g., U.S.-Soviet spacecraft docking, planetary exploration, scientific observations (the Spacelab, Galileo, Landsat, COPAS-SARSAT, GARP), etc.

As for post-Space-Shuttle programs, the unmanned space station project is being developed through the international cooperation of ESA, Japan, Canada, and other countries. Furthermore, progress is also being made in the R&D for the space plane, a completely re-usable type of aero-spacecraft, and the development of the "Shuttle C" and other such unmanned freight-transport shuttles that will make roundtrips between the earth and space stations.

And, on the military side of things, development work is continuing on the gigantic SDI system, which was announced in March 1983.

However, the SDI, Space Station, and Space Plane programs, and other such massive projects all have overrun their initial budgets; in addition to technical difficulties, their development is behind schedule, and their budgets also have to be reduced.

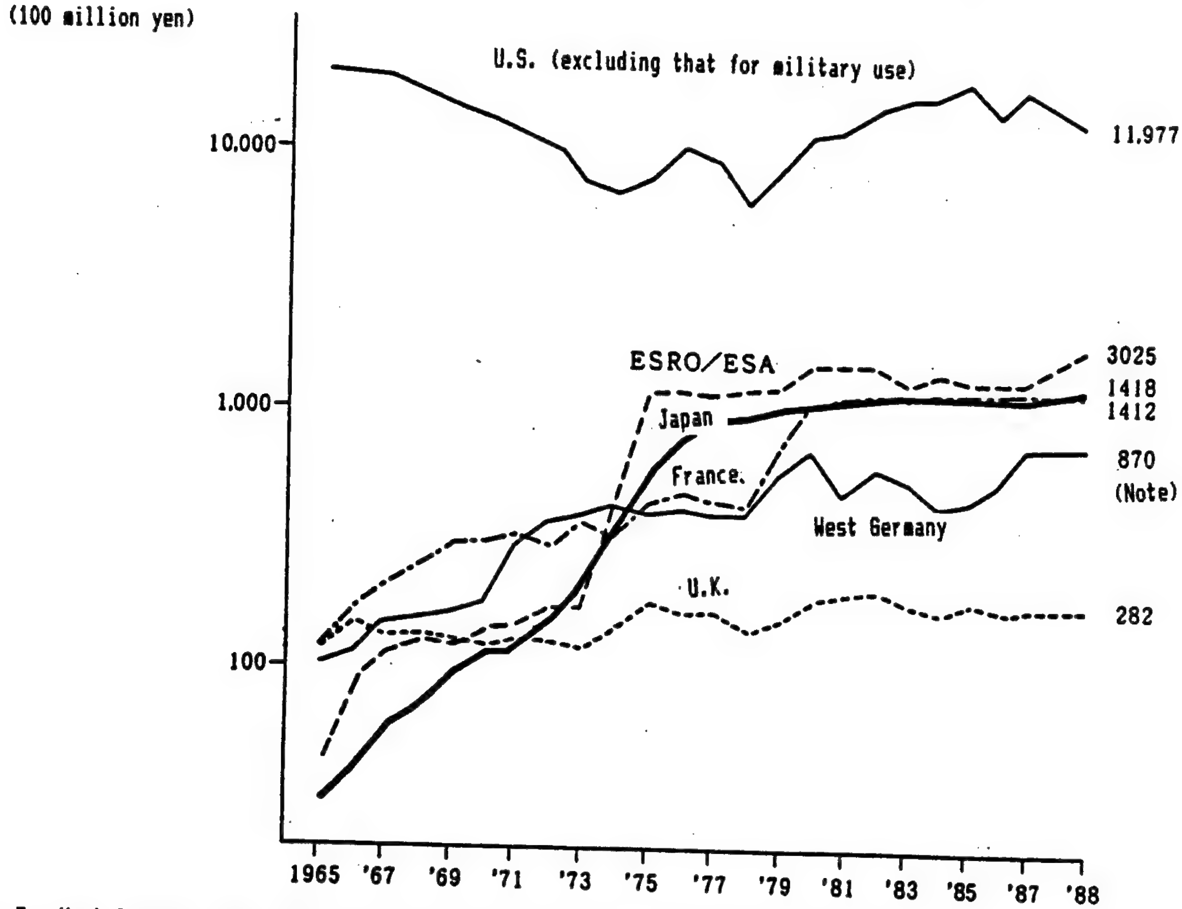
2. Europe's Changes Toward Collaboration

In the early 1980's, ESA programs involving cooperation among European countries steadily brought forth results.

Most of these programs consist of groups of researchers and engineers dispatched from signatory countries. Three-fourths of the ESA budget is financed by the signatory countries' budgets; the individual governments defray 50 to 100 percent of that amount, and the remainder comes from businesses participating in the programs. Also, France, West Germany, the U.K., and Italy bear about two-thirds of the government-defrayed funds.

ESA's strongpoints are that the signatory countries are obliged to participate in scientific satellite programs, basic research, and the like, but participation is becoming voluntary in practical-use satellite programs and other such programs that are directly attendant upon economic interests. Also, each country emphasizes different programs: France, the Ariane rocket program; the U.K., satellites; West Germany, the Spacelab and Columbus programs.

Table 4-4-6 Major Countries' Space Development Budgets



* For West Germany, only budgets relating to researchers and engineers (BMFT) are shown
Data: "The World's Aerospace Industries" Society of Japanese Aerospace Companies, Inc.

Furthermore, the ESA programs are serving to invigorate cooperation among businesses that goes beyond national borders. Consortia are forming and are collectively receiving orders from ESA for concrete development projects and production.

As for the pioneering Ariane rocket, 45% of whose total budget is defrayed by France, it is used by the Ariane Space Company for launches that are entirely business-based. Separate from ESA, the Ariane Space Company was established by CNES, 36 private European companies and 13 banks in 1980 (France finances 68%). In a lesson learned from Europe's defeat, the Ariane is a low-priced rocket in which existing technology was exploited and reliability and economy were stressed. That countries outside Europe, including the U.S., account for more than 50% of its total orders proves the success of the Ariane. In the same way it rivals the U.S. in commercial space activities.

3. Japan's Development

Japan's rocket development, which is linked to its space development, began early in comparison with other countries of the world. It started with the University of Tokyo Space and Aeronautics Institute's research on a pencil-solid rocket, which was launched in 1955. The National Space Development Agency of Japan (NASDA), established in 1969, was put in charge of the development of a large rocket for launching practical-use satellites.

Since the establishment of the Space Activities Commission, Japan's space development has involved increasingly larger-size rockets: NASDA developed the N-1, N-2, and H-1 rockets, the technology for which was introduced from the U.S.; the H-2, whose launch is planned for 1992, has nearly the same launch capability as the Titan and Ariane, the main rockets of the U.S. and Europe, respectively. In contrast to the N-1 and N-2, whose technology was introduced primarily from the U.S., all except for the first stage of the H-1 was domestically developed. Furthermore, all of the H-2 was developed within Japan. Although the cost is comparatively high because Japan launches a smaller number of satellites than the U.S. or Europe, its space development has grown to the point where not only will there be domestic commercial satellite launches in the future, but there is also a possibility that orders will come from overseas.

The development of scientific satellites is based on independent development using parts that are made in Japan, though some parts are procured from foreign countries.

Programs pertaining to the space infrastructure are unlike other programs: some take the form of international cooperation, and long-term, future-oriented R&D is promoted.

1) The manned space station is a joint international project by Japan, the U.S., and Canada. Japan's independently designed experimental modules are the pressurized section, the exposed section, and the supply section.

2) The orbital transfer vehicle (OTV)

3) Amidst the surge in space environment utilization, the space shuttle will transport freight to and from the earth and space stations or other spacecraft. NASDA's current hope is that it will be launched from an H-2 rocket. The National Aerospace Laboratory is now engaged in research on a winged horizontal-take-off-and-landing-type re-usable manned space shuttle. The Institute of Space and Astronautical Science is doing research on a winged "flying body" and other projects.

However, Japan has hardly any experience with space shuttles and is lagging far behind the U.S., which has an abundance of results and experience.

4-4-3 Changes in the International Structure of Aerospace R&D

1. Importants Factors in the Changes

As seen above, aerospace S&T is heading in the direction of international R&D. These changes are illustrated in Figure 4-4-7.

Figure 4-4-7 Direction of the Changes

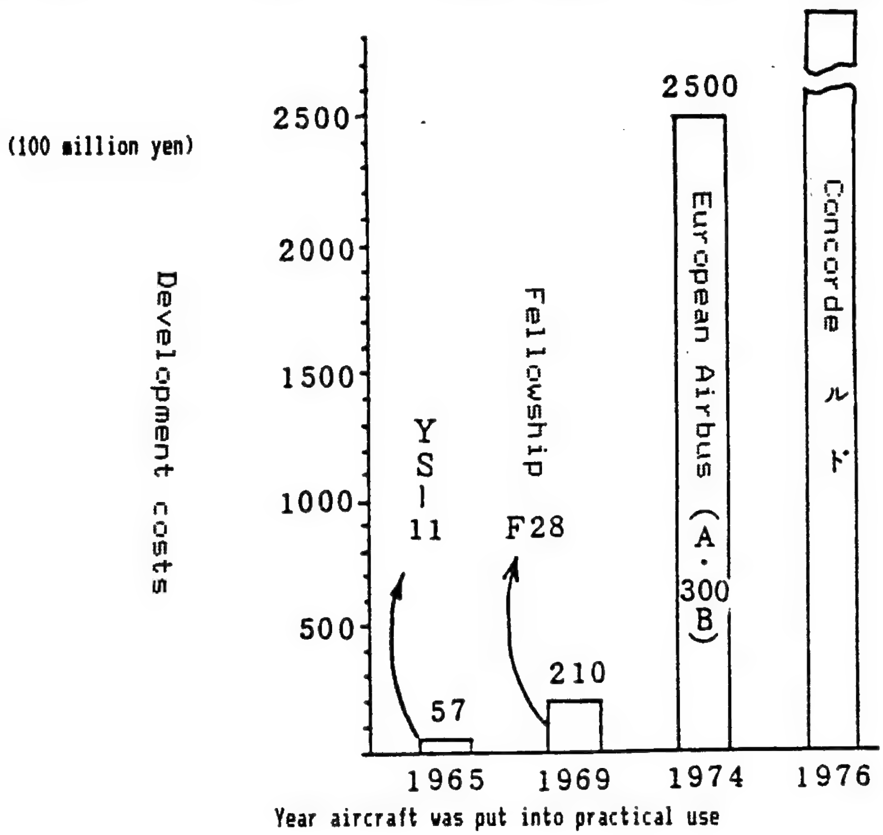
Technological Changes	Changes in the Forms of Development	How Changes are Dealt With	Changes in the International Structure of R&D
More advanced (Higher precision)	Vaster amounts of money for R&D costs	(International)joint development	Technology transfer and joint ownership among nations (among businesses)
More complex (systemized)	Longer development time	Economy stressed (development efficiency)	Equalization of technological disparities among nations
More massive	Greater development risks	From private to national operations (nationalization of enterprises)	Super-large projects (international joint R&D)

A. Vaster Amounts of Money to Cover Aircraft R&D Expenditures

As shown in Figure 4-4-8, there has been a noticeable rise in the R&D costs for civil transport planes, which were out of proportion to the growing sophistication of the technology used. The Concorde supersonic passenger plane (100 seats), in particular, is the most technologically advanced, so its R&D costs are close to four times higher than those for the wide-bodied passenger jet by Airbus (270 seats) that will soon be developed. Since the oil crisis of 1973, R&D costs have become increasingly higher due to the sudden jumps in personnel expenditures and the cost of raw materials. Now, development costs for the A300 class of aircraft are estimated at 800-900 billion yen.

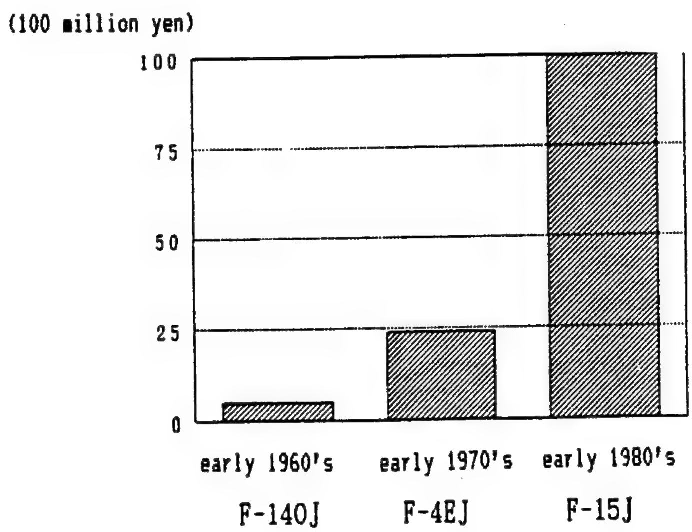
In military aircraft, too, there has been an astoundingly sudden jump in the procurement prices of Japan's main fighter planes (all of which the U.S. develops and Japan produces under license). Shown in Figure 4-4-9, these have increased about 400% in the last ten years. The price of a large U.S. B-1 bomber, estimated as of 1981, for example, is as high as 60 billion yen.

Figure 4-4-8 Aircraft Development Costs



Data: Society of Japanese Aerospace Companies, Inc.

Figure 4-4-9 Vaster Costs of Aircraft Development (Military-Use)



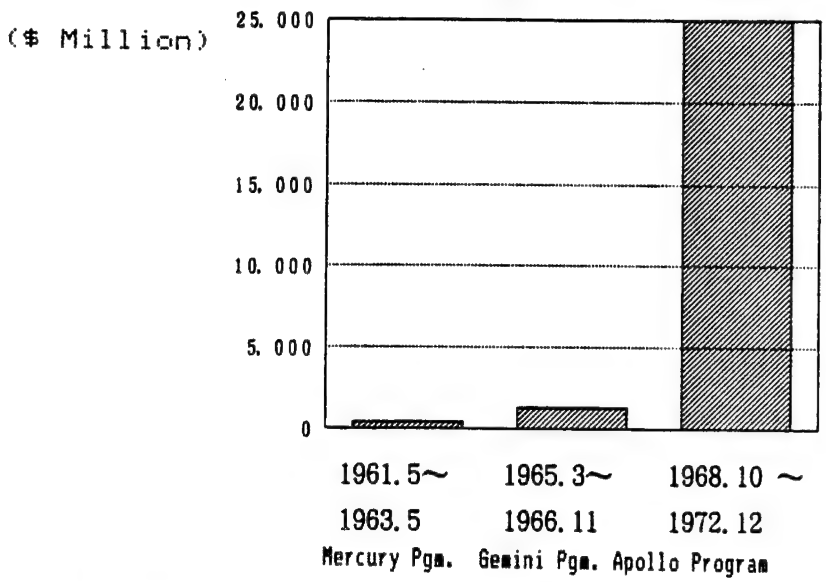
Data: "Outlook on Aviation" The Aerospace Company

With the costs of televisions, automobiles, and other such products for the people's livelihood rising about two to three times over the past twenty years, the tempo of the rise in aircraft prices is fast.

B. Vaster Space Development Costs

If we compare the R&D costs of the three manned flight programs of the U.S. during the 1960's, as shown in Figure 4-4-10, although the scales and development periods of each program are different, what stands out is that the amount of money spent on the Apollo Program was an order of magnitude larger than the costs of the other programs.

Figure 4-4-10 Vaster Space Development Costs



Data: THE SPACE SHUTTLE Report Plan

C. Longer Time for R&D

From initial conceptual design to completion, it takes about thirteen years to develop the latest jet engines that are used in aircraft. There is an obvious difference when this is compared to the four years spent on the J3 jet engine used in Japan's trainer planes that was completed in 1960. Because the demands for reliability and safety in a jet engine, the heart of an aircraft, become more stringent with time, and because there are increasingly more kinds of validation tests that should be carried out on the engines, the development period gets longer due to that alone, and development costs are also rising. The same also holds true for airframes.

D. Increased R&D Risks

It is only natural that the increasing sophistication and complexity of technology makes it difficult to develop new aircraft. Then, as the R&D period gets longer, there is a greater possibility that during that time the development will be subject to economic fluctuations, or that the demands of the market will change. Both of these increase the development risks.

On top of that, it takes 20 to 30 years to recover the development costs. It is estimated that nowadays to go past the break-even point and recover the outlays spent on developing a new civil transport plane, 2000 planes must be produced. However, there are only two or three projects involving civil aircraft developed after World War II where the costs could be recovered.

This makes private-sector R&D difficult and a shift over to nationalization, or financial support and preferential treatment from the government, essential. So, because the burden in a single country is great, binational or multinational collaboration becomes an inevitability.

2. International Joint R&D

In order to overcome the problems occurring with the aforementioned changes in aerospace technology, or the obstacles that make new R&D difficult, countries and businesses are taking various steps, at the center of which is international joint R&D.

A. The Acceleration of International Joint R&D

This often takes the form of the following kinds of joint R&D and joint operations, which include not only Europe but also the U.S.

- Most immense R&D projects in the field of aerospace (the development of civil transport planes, supersonic aircraft, engines for non-government use, rockets, the space station, the space plane, satellite launches, planetary exploration, scientific observations) have come to take the form of joint R&D.

  That trend has become conspicuous since the middle of the 1970's, when development costs increased as a consequence of the sudden jumps in personnel costs and the prices of raw materials due to the oil crises.

- In addition, the operations of joint capital companies (organizations) such as ESA, which was formed by European countries, Arianespace, Airbus Industrie, and the IAE have

been successful and will continue to expand in the future.

- From the perspective of national defense, in the development of fighter planes and other types of aircraft that were often developed independently by each country, there is the same kind of trend with the Eurofighter and the joint Japanese-U.S. FSX development, though it is somewhat special.

B. Economy Stressed

Up until the middle of the 1960's economy did not matter as much in aerospace R&D. That trend was typical of the national space development projects, in particular, and military applications. After the oil crises of 1973, however, sudden jumps in raw material and personnel costs caused development costs to soar all at once. First there were strict inquiries about the economic characteristics of civilian requirements; military requirements then followed.

The following examples are patterns that express the characteristics of future trends:

- The greatest reason why the European countries fell behind the U.S. during the 1960's was economic problems: as R&D projects got larger, businesses and nations ran into financial difficulties. To counter this, the countries created joint capital configurations such as ESA and Airbus Industrie.

- Because of finances and the great risks involved, R&D at even Boeing, the largest civilian transport plane developer and manufacturer in the world, has had to assume a form of international joint development, as seen in the YX/B767 during the 1980's. In engine development, too, the world's largest engine manufacturer, GE, has been carrying out international joint research since the 1970's with SNECMA (France) for the development of the CFM56. During the 1980's that trend has become increasingly noticeable.

C. Development of Nationalization

As a result of the vaster size of projects, the greater risks involved, and economic reasons, most aircraft and space development in the developing countries and in Europe has come to assume a form that is, in substance, national projects.

- In the European countries, aerospace businesses have continued to consolidate since this started in the 1950's. By the 1980's it is becoming a configuration where there is virtually one aerospace business and one engine business (public corporation) in a given country.

- In Japan, although there are several aerospace businesses, most military applications and space development efforts are developed entirely within the national budget. Also, basic research and development projects in the area of civilian aircraft, except for small-scale cases, are developed with financial assistance (50% - 75%) from the government.

- In the U.S., too, from the defense perspective and from the fact that aerospace is the largest export industry, there are tax breaks and considerable funding assistance from the government for military applications, as a matter of course, and civilian aircraft as well. Very much unlike the other industries that produce other goods for the livelihood of the people, the aerospace industry is substantially dependent upon the nation.

3. Changes in the International Structure of Technology

U.S. aerospace still surpasses that of Europe and Japan in advanced technology R&D and in scale.

However, due to the growing size of the industry and the increasing sophistication of aerospace technology that has been discussed up to this point, the shape of R&D must change.

- International joint development, which has become the mainstream in the world since the 1980's, facilitates the transfer of technology among nations, as can be expected. That in turn brings forth the equalization of nations' technology levels. It is an outflow from the U.S., where the level of technology is high, to Europe and Japan, where it is low. In the mainstreams of the 1960's, the U.S. and life sciences production, Japan and Europe mastered U.S. production technology; joint development during the 1980's is bringing about the acquisition of advanced R&D and design techniques.

- Also, because development expenses grow to massive amounts as R&D becomes more technologically advanced and innovative, all the more R&D assumes the form of international joint development. Hence, the transfer of advanced technology will become vigorous unlike ever before.

- Approaching its 45th year since the war, U.S. aerospace is the type that is led by military technology. U.S. technological superiority is maintained by virtue of its basic research that is based on tremendous amounts of defense expenditures, amounts that greatly exceed those of Japan and Europe (60% of all aerospace-related budgets). From the perspective of national defense, military technology R&D has the characteristic of being closed: a single country develops it

and there is no technology transfer to other countries. However, as a result of the recent loosening of East-West tensions, the materialization of the SALT talks, and discussions between NATO and the Warsaw Treaty Organization, the reduction of both the East's and the West's military expenditures is becoming a reality. Because the reduction of U.S. military expenditures during the 1990's is inevitable, the U.S., who has maintained technological superiority that is supported by vast sums of military research expenditures, may be unable to avoid a decline in its relative position.

- As a result of international cooperation and international joint development becoming vigorous in the future, there will be a higher probability that the aerospace industry will head towards realizing super-massive non-military projects, which could not be realized by a single country as a consequence of the enormous R&D costs.

Chapter 5. The Subject of International Structure

In the previous chapters we analyzed the international structure surrounding R&D and examined its characteristics and prospects for the future.

In this chapter we will try to summarize the information gained from these analyses and studies, and will look at future themes.

5-1 Viewpoints on International Structure

In this study we did not clearly define the concept of "international structure." Rather, our main objective was to, from the viewpoint of scientific and technical R&D, grasp the global relationships that are undergoing great changes, while keeping in line with the realities of the current state of affairs.

As for this "international structure," though, we established the following viewpoints in this study:

(1) The objectives in analyzing the international structure of R&D are to survey R&D strength from a global, overhead view; and to understand the main factors in that growth and change in view of geographical or national growth processes and their interrelationships.

(2) The international structure of R&D is taken to be the historical relationships that dictate the manifestation of R&D strength, the nature of which is the creation of scientific knowledge and technology.

Those relationships have many layers: from the geographical or national level; to organizations such as businesses and universities; to the individual level of researchers and engineers.

(3) The international structure of R&D is also taken to be the relationships in the distribution of R&D resources, as the manifestation of R&D strength.

That is, the structure of the international distribution of R&D resources--R&D expenditures, research personnel, and then, knowledge and information.

From these points of view it naturally follows that R&D, as a process that forms scientific knowledge and technology, is closely related to socio-economic structure.

The international structure of R&D can also be seen in terms of

global-scale competitive and cooperative relationships, from the geographical or national level down to the organizational and individual levels. In this case competition does not simply mean rivalry that centers on corporate profits. It also involves competition for the sake of mutual stimulation and activation of researchers.

5-2 Opinions on International Structure

Through international comparisons of R&D strength, as shown in Chapter 1, we analyzed from the aforementioned viewpoints the relative superiority and the geographical or national characteristics of the R&D strength that are manifest in the present-day state of affairs.

The following became clear from these analyses:

- In the relationships among the advanced countries of Japan, the U.S., and Europe, great changes can be seen in the relative superiority of R&D strength. Japan's growth is particularly remarkable; conversely, a drop in the relative position of the U.S. is evident.

- Japan is virtually passing up the U.K., France and West Germany in R&D strength. Although on an overall scale its strength does not match that of the U.S., when viewed in a comparison of the population of citizens that receive the fruits of R&D as economical and social lifestyle advances, Japan has already reached the same level as the U.S.

- On the other hand, in Thailand and Korea, countries that represent the NIES and ASEAN, progress is also being made in providing the conditions for elevating R&D strength. In the case of Korea, especially, great changes are evident in aspects such as R&D investments and the education of research personnel.

- With respect to technology trade and high-tech product trade between Japan and the U.S., striking differences are seen in their R&D strength viewed in terms of population.

  Important factors implied in those respects are: the fact that technology exports from the U.S., which hold a tremendous weight and which pioneered the world's post-war technology, were essential in the reconstruction and development of Japan and Europe; and the development of multinational enterprises in the U.S.

Building upon the knowledge gained from these kinds of analyses, Chapter 2 analyzes the processes of growth in R&D strength as

historically ordained attributes that characterize international relationships and the state of relative superiority thereof. In these analyses, from the international competitive and cooperative relationship axes setup, the U.S. is categorized as a country in a leadership position; Japan, as a country that develops later; then Korea and Thailand as countries that develop even later. As a result, the following points were clarified:

- As the country that leads in R&D, the U.S. fulfills a roll as an outrider for science that is grounded on basic research, owing to the powerful support given by the Federal Government for research. Also, as a result of the multinational development of the private sector, the U.S. plays a major role in the creation of scientific knowledge and technology, and the dissemination and transfer of those results throughout the world.

  Although government support exhibits changes as a result of policy measures, the government still defrays a large percentage of R&D expenditures. In that, the government's leadership role in S&T is sustained.

  Further, these administrative measures also have the characteristics of being basic research and military research.

- On the other hand, Japan, which is categorized as a late-developing country, absorbs the scientific knowledge and technology of the country that is the leader (the U.S. can be seen as this). Japan has strived to form an S&T base by pouring its energy into applications development. In that, the vigor of private businesses was the most important reason for growth.

  The role of the government with respect to active investments in R&D and the education of personnel was something that supplemented this private-sector vitality.

- Then, Korea and Thailand, the later-developing countries, are actively striving to absorb and introduce scientific knowledge and technology from the leading country and from the late-developing country Japan. The roles of their governments are oriented towards forming an S&T foundation, particularly an R&D base. In Korea, the vigor of the private sector, which moves at a different pace, is gaining power, and that base formation is reaching the first step--the promotion of independent R&D.

  In Thailand, however, with the vitality of the private sector still lacking in strength, the formation of an S&T base by the government is becoming an important subject.

- It is apparent from this competitive-cooperative-relationship-axes analysis that a global order is being formed in the dissemination and transfer of scientific and technological knowledge and technology.

  Furthermore, in the past, when the position of the U.S. as the strongest nation surpassed all others, these relationships were comparatively stable, but as late-developing Japan's R&D strength grows, this relationship becomes unstable; it points to a situation where competition becomes intensified.

  This instability manifests itself in the international dispersion of leading R&D strongpoints and those main R&D bodies.

- For Japan, which has grown this far, it is thought that the leading country's governmental R&D support and then the multinational development of its business sector, which are seen in the U.S., are important points to take into consideration for promoting R&D in the future.

Chapter 3 is an analysis that includes a questionnaire survey of how Japan's R&D strength, having grown this far, manifests itself as corporate-based activities in international relationships. The reason why attention is focused on corporations is that the current state of corporate activities, which are regarded as the most important factor in Japan's growth, may suggest Japan's directions in the future.

The following became clear from this analysis:

- The establishment of Japanese corporate research laboratories abroad is progressing, and much of that is in the U.S. In the industries that are regarded as R&D-intensive--chemicals, electric machinery, machinery--the objective of the R&D carried out at these labs is not to introduce overseas technology, but rather the exploration for the seeds of leading-edge technology for the next generation of technology, and as a way to cope with local market needs. Furthermore, the utilization of local personnel is becoming an important factor.

  This step can be regarded as something that serves to mutually complement the international joint project initiatives that are being promoted by the government.

Chapter 4 analyzes how the kinds of structural changes above manifest themselves in individual R&D domains. It takes computer science, the life sciences, superconducting materials, and aerospace into account.

- In computer science, the leadership of the U.S. is clearly indicated in the trends seen in research papers.

  In the aspect of applications, however, the progress being made by Japan and Europe, too, is intensifying. Although the U.S. plays a great role in creating and disseminating scientific knowledge and then technology, the growth of Japan and Europe necessitates a new framework for international cooperation, which changes are gradually bringing about.

  In the life sciences, the rapid growth of biotechnology, which got its start with recombinant genetic technology during the mid-1970's, is clearly revealed in the aspects of research papers and patents. Here, too, the U.S. plays the leading role.

  Nevertheless, the timelag with Japanese and European R&D progress is short. It is evident that the current state of affairs is one in which both basic research and applications are moving forward synchronously in the developed countries.

  Also, cooperation between universities and the private sector plays an important role in biotechnology; moreover, through the activities of U.S. bioventures, it is accelerating the activation of R&D throughout the world.

- In the field of superconducting materials, Japan and the U.S. lead the world in R&D, and there is no timelag between the two countries. It is obvious that R&D is progressing synchronously.

  Furthermore, in this synchronous progress, researchers' independent, international collaborative efforts at the basic scientific research level are being spawned one after another. It is a situation that attracts attention.

  On the other hand, a difference in the way Japanese and U.S. businesses deal with superconductor R&D is seen in the aspects of research papers and patents. The slowdown in U.S. corporate activities stands out against the concentrated measures taken by Japanese businesses.

- In aerospace, though the overwhelming strength of the U.S. still leads the world, it is coming to a situation where international joint R&D is essential, as in the joint European projects and the joint Japanese-U.S. and Japanese-U.S.-European projects.

The opinions expressed above point to the advent of great changes in the post-war international relationships that are expressed in

the form of international R&D structure. Although there is little difference in the leadership of the U.S., which has a tremendous accumulation of scientific knowledge and technology and still evinces great R&D strength, the growth of Japan brings about synchronous R&D development in the world, as seen in superconductor R&D, and it gives rise to the dispersion of international R&D centers. This synchronous R&D development suggests the formation of a new framework for researchers' and businesses' independent international cooperation.

Also, the formation of a framework for new international cooperation, which started with the joint research projects of Japan, the U.S., and Europe, is becoming essential in domains such as computer science and aerospace, where the foundation of knowledge and technology from the past has a great significance.

We can also think of these points as asking again about the roles of the developed countries with respect to the entire world, which includes the developing countries of Asia and other regions, Eastern Europe, and the Communist Block countries.

5-3 Subjects for the Future

An analysis of the international structure should not be limited to only the relationships among the developed countries. In this study, too, we take into consideration Korea, an Asian NIES country; and Thailand and Indonesia, of the ASEAN countries. However, the basic data that we could use for these countries was limited.

For basic data on the entire world, our materials were limited to UNESCO data, which is too meager for looking at the world as a whole.

What is wanted aboveall is that the gathering and accumulation of basic data, such as statistics, be made more replete on a global scale. This is also something that would be indispensable in Japan's future international position and role.

Also, from the research done for this study, the following points came up as subjects that should be investigated on another occasion:

(1) We would like to have a system of indicators established that can compare R&D strength (i.e., the power to produce scientific knowledge and technology) in the relationships among the countries of the world that differ historically and population-wise. Indicators relating to basic and scientific research, in particular, would be needed.

(2) What kind of changes to historically-ordained structures can Europe's circumstances within international relationships bring about is a subject that must be investigated.

In particular, the unification of Europe and the changes in the U.S.S.R. and Eastern Europe are important as structural themes that surround S&T and R&D.

(3) As for the relationship between Japan and the U.S., which we must say is the central issue for Japan, how should a new framework for competition and cooperation be formed, and what kind of framework should that be? What should also be investigated is how we should regard Japan's position in Asia and the role that it should play there.

(4) Then, although we did not cover these themes in this study, how Japan's researchers, engineers, and the main R&D bodies of its businesses and laboratories are striving, within international relationships, to deal with the creation of new knowledge, and what those subjects are, should be investigated in line with the actual state of affairs.

III. Collected Data

Attached List 1. High-Tech Product Classifications by the U.S. Department of Commerce (DOC3)

	High-Tech Product Group	Tangible Products
1	Guided missiles and space rockets	Rocket engines and spare parts
2	Communications equipment and electronic parts	Telephone and telegraph equipment, radio and television reception and transmission equipment, communications equipment, sonar, semiconductors, tape recorders
3	Aircraft and spare parts	Commercial aircraft, helicopters, aircraft engines, spare parts
4	Office equipment, computers	Computers, input-output devices, memory devices, desktop calculators, copiers, spare parts
5	Weapons and spare parts	Non-military-use weapons, shotguns, sport guns, explosives
6	Medicines	Vitamins, antibiotics, hormones, viruses
7	Inorganic chemical substances	Nitrogen, sodium hydroxide, inert gases, inorganic dyes, radioactive substances and compounds thereof, specified nuclear power materials
8	Specialized equipment	Industrial process control equipment, optical devices, lenses, navigational equipment, medical treatment equipment, photographic equipment
9	Engines, turbines, and spare parts	Generators, diesel engines, non-automotive gasoline engines, gas turbines, hydraulic turbines
10	Plastic materials, synthetic resins, rubber, fibers	All kinds of concentrated chemical substances, multi-concentrated substances, polymers, multi-additive substances, copolymers, synthetic resins, non-cellulose/cellulose fibers

Data: Nikkei Science "U.S. Technology Strategy"

Attached List 2. Bilateral S&T Cooperation

1. Japanese-U.S. Cooperation in Scientific and Technical R&D

• Research on crustal plate movement	Ministry of Posts and Telecommunications-NASA
• OPEN Project	Ministry of Education-NASA
• Joint research on Halley's Comet	Ministry of Education-NASA
• Saturn exploration project	Ministry of Education-NASA
• Life sciences in the Spacelab	Science and Technology Agency-NASA
• Joint tesar project	Ministry of Education-NASA
• X-ray astronomy	Ministry of Education-NASA
• Marine dynamics	Science and Technology Agency; Meteorological Agency; Maritime Safety Agency; University of Tokyo; Tokai Women's College-NASA
• Cloud height measurements using satellite stereoscopic photography	Science and Technology Agency; Meteorological Agency- NASA
• Characteristics of snowdrifts	Science and Technology Agency-NASA
• Possibility of evaporation calculations	Science and Technology Agency-NASA
• Exchange of experimental data from communications satellites	Science and Technology Agency; Ministry of Posts and Telecommunications-NASA
• Trans-Pacific balloon observation project	Ministry of Education-NASA
• Joint research on the sun	Ministry of Education-NASA
• Research on winds and waves generated by typhoons	Science and Technology Agency; Meteorological Agency-NASA

• Marine biological resources	Science and Technology Agency; Ministry of Agriculture, Forestry, and Fisheries; Tokai Women's College-NASA
• MOS-1 data reception	Science and Technology Agency-NASA
• Geodetic and geodynamics research by means of satellite laser ranging	Maritime Safety Agency-NASA
• Tropical rainfall observation satellite project	Ministry of Posts and Telecommunications-NASA
• Marine (ground) remote sensing research	Science and Technology Agency; MITI-NASA
• Earth observations using a polar-orbiting platform	Science and Technology Agency-NASA
• Balloon-mounted infrared telescope	Ministry of Education-NASA
• Infrared astronomy	Ministry of Education-NASA
• Research on outer-space VLBI (Very Long Baseline Interferometry)	Ministry of Education; Ministry of Posts and Telecommunications-NASA
• Space Shuttle utilization project	Science and Technology Agency-NASA
• Landsat data reception	Science and Technology Agency-NASA
• Space station project	Science and Technology Agency-NASA
• ROSA-IV project	Science and Technology Agency-NRC
• Doublet-III project	Science and Technology Agency-NRC
• Research on high-temperature gas reactors	Science and Technology Agency-DOE

• Neutron scattering	Science and Technology Agency, Ministry of Education-DOE
• Nuclear physics	Science and Technology Agency-DOE
• Effects of carbon dioxide on climate	Ministry of Education, Meteorological Agency-DOE
• Diesel exhaust gases	Environmental Agency-DOE
• Liquified gas fuel safety and environmental regulatory assessment project	MITI, Ministry of Transport-DOE
• Effect of electromagnetic fields on living organisms (electric fields)	MITI, Hokkaido University -DOE
• Effect of electromagnetic fields on living organisms (magnetic fields)	Science and Technology Agency-DOE
• Conservation of resources	MITI, Science and Technology Agency-DOC
• Toxicological research	Ministry of Health and Welfare-HHS
• Research on alcoholism	Ministry of Health and Welfare-HHS
• Comparative-cultural research on factors in the development of geriatric mental disorders	Ministry of Health and Welfare-HHS
• Promotion of preventative vaccination and the development of vaccines	Ministry of Health and Welfare-HHS
• Experimental animal science (primates)	Ministry of Health and Welfare-HHS
• Experimental animal science (non-primates)	Ministry of Health and Welfare-HHS

• Recombinant DNA research	Science and Technology Agency, Ministry of Education-HHS
• Development of anti-viral substances	Science and Technology Agency, Ministry of Education-HHS
• Basic and epidemiological research on high blood pressure/heart disease and eating habits	Ministry of Health and Welfare-HHS
• Processing/poison removal and disposal of noxious substances	MITI-EPA
• Technology for restricting nitrous oxides	MITI-EPA
• Epidemiological research on environmental diseases	MITI-EPA
• Research on marine pollution due to the dumping of wastes	Science and Technology Agency-EPA
• Experiments on ecological concentrations of fish	Environmental Agency-EPA
• Research on the prediction and control of avalanches and landslides	Science and Technology Agency, Ministry of Construction, Hokkaido Development Agency-USDA
• Illnesses of trees in forests	Ministry of Agriculture, Forestry, and Fisheries-USDA
• Research on food hygiene regulations (salmonella)	Ministry of Agriculture, Forestry, and Fisheries-USDA
• Comprehensive management of harmful insects	Ministry of Agriculture, Forestry, and Fisheries-USDA
• Comprehensive research on the effective utilization of natural energy in agriculture, forestry, and fisheries	Ministry of Agriculture, Forestry, and Fisheries-USDA Ministry of Agriculture,

• Use of radiation to control damage to foodstuffs during transportation and storage	Forestry, and Fisheries, Science and Technology Agency-USDA
• Agricultural-production-oriented biotechnological development and applications	Ministry of Agriculture, Forestry, and Fisheries-USDA
• Research on the cellular genetics of crop species	Ministry of Agriculture, Forestry, and Fisheries-USDA
• Prevention of crop deterioration and contamination after harvesting	Ministry of Agriculture, Forestry, and Fisheries-USDA
• Biomass conversion	Science and Technology Agency; Ministry of Agriculture, Forestry, and Fisheries; MITI-USDA

2. Japanese-French Cooperation in Scientific and Technical R&D

- Research on the safety of light-water reactors
- Water management in rivers, lakes, and marshes
- Atmospheric pollution counter-measures
- Cooperation in the field of construction
- Large scientific apparatuses
- Space communications
- S&T information
- New materials
- Electronics
- Energy (new energies, energy conservation)
- Biotechnology
- Space fields (except for space communications)
- Agricultural research
- Quality of urban environments (amenities)
- Aeronautical engineering

3. Japanese-German Cooperation in Scientific and Technical R&D

- Fast breeder reactors
- Labor safety and health
- Space
- Traffic technology
- Telecommunications technology
- Data processing
- Mineral resources research

- Materials science technology
- Anti-energy physics
- Research on high-density nuclear substances by means of heavy ion beams
- Machine technology

4. Japanese-Canadian Cooperation in Scientific and Technical R&D

- Space physics
- Earth observations
- Communications and broadcasting satellites
- Ionospheric observation satellite
- Videotex
- High-definition television broadcasting
- Plant breeding
- Recombinant DNA microorganisms
- Improving wheat varieties by means of doubling haplonts and cell cultures
- Improving and propagating alfalfa using tissue culture techniques
- Designing and carrying out paving in arctic regions
- Superconducting magnetic-levitation railways
- Harbor and coast engineering
- Isolated hydosphere experiments
- Particle-bunching experiments using automatic sediment traps
- Research on atmospheric-marine carbon dioxide exchange in the North Pacific
- Research in connection with environmental investigations attendant upon the development of sea-floor mineral resources
- Commercial development and utilization of non-crystalline metals
- Food product safety
- Comprehensive insect-pest control
- Research on buckwheat ecosystems cultivated in different climates
- Fodder digestion by cellulose-dissolving cells
- Chemical identification of naturally-occurring substances and residual agricultural chemicals
- Optimization of the environment around plant roots in order to improve yields of major crops
- Improved greenhouses for vegetable production
- Measuring aromatic composition
- Breeding fruit trees and interchanging reproductive characteristics
- Sclerotium [a plant disease] in soybean and oil-material crops
- Post-harvesting processing and storage of Cruciferae [rape seed plant] crops
- Enriched nutrient value of water quality

- Advanced sewage processing
- Satellite meteorology
- Climatic fluctuations
- Atmospheric pollution
- Advanced processing of industrial wastewater
- Snow damage prevention
- Methods for assessing the toxicity of gases when fires occur in buildings
- Research on wind- and earthquake-proof structures
- Behavior of concrete at low temperatures
- Coal liquification
- Thermonuclear fuel technology
- Renewable energies
- Alcohol for use as an automobile fuel
- Improving heavy oils
- Computer-based image processing applications
- Advanced systems for manufacturing and resources production
- Integrated magnetic sensors
- Geodynamics and crustal plate movements
- Research studies on VLBI experiments
- Research on permafrost layers
- Meson science
- Laser applications
- Fluid body experiments in a micro-gravity environment
- Electronic sea charts
- Crystal chemistry in fine ceramics
- Assessing year-to-year damage and predicting the extra-long life of structural materials
- Applications of multiparameter radar in river and road management
- Manufacturing liquified fuels from biomass
- Bionics: the integration of sensory systems' information in cognitive systems

5. Japanese-Australian Cooperation in Scientific and Technical R&D

- Crop physiology
- Chemical analysis of growth-regulating substances, including those of plants
- Biotechnology
- Recombinant DNA
- Neutron supplement treatment of malignant melanomas
- Plant breeding
- Development and utilization of plant genetic resources
- Domestic animal breeding
- Interrelationships of genomes in the cell nuclei, leaf margins, and mitochondria of higher plant cells
- Nuclear physics

- Mid-level and very-high-level aeronomy
- Research on celestial bodies using balloons
- Research on the properties of substances under very high pressures
- Plasma physics and nuclear fusion research
- Satellite-based precision frequency and time comparisons
- Geodesic research by means of satellite laser ranging
- Exospheric and magnetospheric research using satellites
- Low-level atmospheric physics
- Objective analyses and numerical meteorological predictions of atmospheric motion
- Meteorological satellite data
- Effects of carbon dioxide on the atmosphere
- High-temperature instrumentation and control technology
- Research on x-ray analysis methods
- Fine structures in new ceramics
- Experimental petrology
- Antarctic research
- Very-high-precision optical instrumentation technology
- Development of new ceramic and carbon materials
- Development of techniques for improving the durability of concrete structures
- Optical fibers and pattern information processing
- Fluidized-bed combustion technology
- Technology for preventing marine pollution
- Research on the tectonics of island arc/trench systems in ocean areas that are on Indian Ocean and Pacific Ocean plate boundaries
- Research on eddy currents
- Marine biology
- Technology for developing ocean-floor mineral resources
- Research on technology for stable seacoast formation
- Equipment and techniques for measuring crustal plate heat flow

6. Japanese-Korean Cooperation in Scientific and Technical R&D

- Development of steel manufacturing processes
- Development of new biological activation substances and biological activation experiments
- Development of polymer materials for use in medical treatment
- Development of processes that utilize genetic engineering for mass producing physiological activation substances
- Research involving remote sensing and the processing of that data
- Satellite-based time comparison research
- Development of welding technology
- Development of superlattice elements
- Development of chemical sensors

- Utilization of technology related to new DNA singularities and genes
- The search for plant physiological activation substances and the development of uses for those substances
- Research on the climate of northeast Asia
- Low-level radioactive waste processing and disposal
- Educating and training nuclear-power-related personnel
- Light water reactor accident analysis
- Nuclear fuel post-irradiation experimental techniques
- Emergency measures for protection against radioactivity in areas near nuclear power plants
- Joint development of a catalytic combustion gas turbine
- Research on applications of thermoelectric materials
- Development of machining-information-sensing technology
- Research on the structure of ocean currents in the Tsushima Straits
- Research on the development of microorganisms that cause diseases in harmful mountain and forest insects
- Research related to high-energy physics experiments using the Tristan accelerator
- Research on forming and sintering diamonds
- Basic research on inorganic materials
- Hydrogen production by means of biological processes
- Establishing technology to control perennial weeds in paddies
- Synthesis of organoflouric compounds
- Effective utilization of volcanic ejecta
- Research in connection with identifying the sources of ocean pollution due to oil and other kinds of spills and clean-up methods
- Nuclear fuel post-irradiation experimental techniques
- Educating and training nuclear-power-related personnel
- Assessment of radioactive waste processing methods
- Manufacturing radioactive isotopes
- Development of systems for gathering and processing information on nuclear power plant accidents and failures
- Development of technology for assessing nuclear power plant safety
- Development of technology for analyzing the earthquake resistance of nuclear power plants
- Development of technology for inspecting nuclear power plants
- Research on the processing and utilization of rice and rice starches
- Establishing computerized systems for real-time exposure assessment in nuclear power plants when accidents occur

7. Japanese-Chinese Cooperation in Scientific and Technical R&D

- Research on the comprehensive development and utilization of tropical and sub-tropical microorganisms and plants

- Industrial tests based on the construction of a pilot plant for niobium extraction and continuous steel manufacturing from pig iron
- Joint VLBI research
- Research on the development of flocks of SPF (Specific Pathogen Free) chickens
- Research on developing and changing wild animals into experimental animals
- Research on preventing atmospheric pollution and other kinds of environmental pollution
- Effects of the Kuroshio on its environment and biological resources
- Mechanisms of crop damage by cold weather and the development of technology for protecting against that
- Research on cosmic rays by means of large neutron counters
- Measures for counteracting the subsidence of harbors by siltation
- Research on the general use of complex ores containing rare metals
- MLS (Microwave Landing System) R&D
- Research on technology for preventing marine pollution due to oil spills and oil identification technology
- Biomechanical research in connection with vital measurements technology
- Geodetic research using EGP [expansion unavailable]
- Research on the prevention and mitigation of earth and sand disasters
- Oxysaccharification of cellulose
- Research on artificial crystals by means of polyvinyl alcohol hydrogel
- High-performance equipment in thermo-engineering
- "Jiwan" chemical catalyzer technology

8. Japanese-Indonesian Cooperation in Scientific and Technical R&D

- Research on the tectonics of island arc/trench systems in ocean areas that are on Indian Ocean and Pacific Ocean plate boundaries
- Research on the comprehensive development and utilization of tropical and sub-tropical microorganisms and plants
- Research on physiological activation substances included in tropical plants
- Research on new insect-pest control techniques
- Research on microorganism enzymes that have uses in industry
- Searching for and utilizing microorganisms in activated agricultural chemicals
- Searching for fermentation microorganisms and utilizing those in the food product industry

- Searching for and utilizing medicinal activation plants
- Searching for and utilizing agricultural chemical activation plants
- Research on more advanced remote sensing technology and its applications

9. Japanese-Indian Cooperation in Scientific and Technical R&D

- Research on open-air corrosion of metals and alloys
- Ionospheric observations by means of ETS-II (Engineering Test Satellite) radio waves
- Research related to the preservation, development, and utilization of plant genetic resources
- Research related to the use of cell cultures in crop breeding
- Extracting meteorological information from satellite images
- Development of methods for predicting the concentrations of atmospheric and water pollution that accompanies industrial activity
- Research on methods for real-time prediction of flood wash-aways

10. Japanese-Brazilian Cooperation in Scientific and Technical R&D

- Research on welding technology
- Research on pegmatite
- Resources database systems
- Comprehensive control of soybean insect pests
- Technology for enzymatic conversion of cellulosic biomass
- Elucidating the structure and expression control mechanisms of protein genes in plants and microorganisms
- Development of methods for exchanging and assessing genetic resources
- S&T for preventing meteorological disasters such as flood and drought damage
- Fermentation engineering and microorganism engineering
- Fermentation engineering, enzymatic reactors, and genetic engineering
- Geothermal energy research

Attached Table 3. Multinational Scientific and Technical Cooperation

Scientific and Technical Cooperation Arising From Summit Meetings of the Major Developed Countries

- Solar power generation
- Controlled thermonuclear fusion
- Photosynthesis
- Fast breeder reactors
- Food technology
- Aquaculture
- Remote sensing from space
- High-speed railways
- Developing countries' residential and urban planning
- High-tech robots
- Effects of new technologies on mature industries (Japan is not participating)
- Biotechnology
- New materials and standards
- New technologies applied in education and professional training and in culture (Japan is not participating)
- Social receptiveness to new technologies
- Biological sciences
- Light-energy physics
- Solar system exploration

Attached Table 4. Numbers of Research Papers in Computer Science (Results of INSPEC searches)

Year	Japan Business	Japan Universities	Japan Other	Japan Total	U.S. Business	U.S. Universities	U.S. Other	U.S. Total
1977	451	738	335	1,524	2,724	4,478	2,762	9,964
1978	571	1,087	461	2,119	3,329	5,701	2,718	11,748
1979	459	930	412	1,801	3,429	5,727	2,720	11,876
1980	583	1,056	457	2,096	3,587	5,465	2,728	11,780
1981	511	1,009	428	1,948	4,235	6,242	3,464	13,941
1982	706	1,132	525	2,363	4,121	5,226	2,969	12,316
1983	810	1,216	550	2,576	5,067	6,596	3,769	15,432
1984	973	1,314	642	2,929	5,343	7,585	4,125	17,053
1985	1,038	1,753	951	3,742	4,287	8,853	4,196	17,336
1986	1,247	1,998	1,265	4,510	4,709	10,564	4,765	20,038
1987	1,343	2,112	1,109	4,564	4,943	13,066	5,452	23,461
1988	1,316	1,962	1,136	4,414	4,658	13,470	5,570	23,698
1989	866	1,408	779	3,053	2,763	9,988	3,997	16,748

Year	U.K. Business	U.K. Universities	U.K. Other	U.K. Total	West Germany Business	West Germany Universities	West Germany Other	West Germany Total
1977	289	1,055	561	1,905	404	703	675	1,782
1978	375	1,332	653	2,360	449	828	772	2,049
1979	392	1,381	658	2,431	464	897	809	2,170
1980	331	1,311	660	2,302	478	896	876	2,250
1981	388	1,501	730	2,619	460	956	841	2,257
1982	339	1,293	603	2,235	423	737	749	1,909
1983	580	1,406	820	2,806	697	855	970	2,522
1984	599	1,605	1,017	3,221	666	1,039	989	2,694
1985	721	1,788	1,234	3,743	602	1,024	869	2,495
1986	726	2,156	1,421	4,303	734	1,394	1,122	3,250
1987	761	2,304	1,418	4,483	687	1,487	1,075	3,249
1988	653	2,881	1,443	4,977	781	1,690	1,072	3,543
1989	412	2,218	1,085	3,715	532	1,091	673	2,296

Year	France Business	France Universities	France Other	France Total
1977	25	230	400	655
1978	17	303	493	813
1979	20	318	466	804
1980	15	349	555	919
1981	30	413	598	1,041
1982	10	319	507	836
1983	16	246	537	799
1984	21	333	607	961
1985	20	415	860	1,295
1986	35	575	1,195	1,805
1987	20	584	1,179	1,783
1988	43	595	1,224	1,862
1989	16	438	903	1,357

Attached Table 5. Numbers of Research Papers in the Life Sciences
(Results of BIOSIS searches)

Year	Japan				U.S.			
	Business	Universities	Other	Total	Business	Universities	Other-	Total
1975	0	23	13	36	0	41	13	54
1976	40	511	172	723	26	933	480	1,439
1977	349	4,602	1,033	5,984	632	18,617	9,461	28,710
1978	601	7,868	1,760	10,229	1,447	40,070	20,141	61,658
1979	785	11,536	2,685	15,006	1,917	62,078	30,035	94,030
1980	827	12,431	2,872	16,130	1,647	55,212	27,717	84,576
1981	772	12,919	3,329	17,020	541	16,804	8,456	25,801
1982	806	12,058	2,787	15,651	482	14,183	7,464	22,129
1983	790	11,050	2,539	14,379	494	12,204	6,368	19,066
1984	985	15,998	3,930	20,913	888	19,000	9,615	29,503
1985	1,343	19,839	4,927	26,109	1,395	22,092	11,978	35,465
1986	1,711	20,160	5,433	27,304	2,863	27,978	16,265	47,106
1987	2,165	22,402	5,746	30,313	4,019	25,286	15,852	45,157
1988	2,230	23,915	6,339	32,484	3,781	26,654	16,089	46,524
1989	2,259	20,940	5,555	28,754	3,944	30,981	19,100	54,025

Year	U.K.				West Germany			
	Business	Universities	Other	Total	Business	Universities	Other	Total
1975	0	4	12	16	0	7	18	25
1976	8	181	215	404	9	233	312	554
1977	141	3,135	3,238	6,514	95	5,286	2,073	7,454
1978	270	5,957	5,833	12,060	150	4,756	3,625	8,531
1979	407	8,770	8,853	18,030	290	7,412	5,275	12,977
1980	319	6,757	6,689	13,765	258	6,241	4,593	11,092
1981	194	5,287	4,775	10,256	228	4,319	3,628	8,175
1982	107	5,620	4,889	10,616	231	4,281	3,553	8,065
1983	94	4,748	4,254	9,096	167	3,308	2,780	6,255
1984	162	5,836	5,563	11,561	332	5,172	4,531	10,035
1985	232	7,112	6,492	13,836	446	6,408	5,599	12,453
1986	312	8,096	7,755	16,163	734	7,624	6,231	14,589
1987	406	9,371	8,909	18,686	869	8,556	6,492	15,917
1988	418	9,463	9,254	19,135	794	7,713	6,286	14,793
1989	418	8,870	9,090	18,378	773	8,073	6,782	15,628

Year	France			
	Business	Universities	Other	Tot
1975	0	34	100	134
1976	10	280	810	1,100
1977	86	2,204	5,620	7,910
1978	140	3,032	8,734	11,906
1979	258	4,924	13,270	18,452
1980	146	3,934	11,672	15,752
1981	32	3,456	11,422	14,910
1982	28	3,626	11,676	15,330
1983	16	3,320	10,162	13,498
1984	46	4,808	15,620	20,474
1985	62	4,790	18,360	23,212
1986	130	5,684	20,706	26,520
1987	222	5,886	22,962	29,070
1988	196	6,064	23,652	29,912
1989	190	5,392	22,674	28,256

Notes

*1 International research-paper comparisons in which databases were utilized

1. Search overview

In general, when we use bibliographical databases to conduct international comparisons of research papers, there usually are not any codes within the database records for identifying the nationality of the author or the organization with which the author is affiliated. The databases used in this investigation, BIOSIS PREVIEWS and INSPEC, are no exception. So, for country and sector classifications, we used the address and title, respectively, of the organization that the author of the research paper is affiliated.

In concrete terms, when "USA" or "US" was included in the address of the author's affiliated organization, we classified it as America; when "JAPAN" was in the address, we classified it as Japan. We also did the same kind of thing with sector classifications; the table below shows the relationships between search words and classifications.

Table Relationships Between Search Words and Classifications

	BIOSIS PREVIEWS	INSPEC
Japan	JAPAN, JPN, JAP, JP	JAPAN
U.S.	USA, US	USA, US
U.K.	ENGLAND, UK, GB, GBF, SCOTLAND, WALES	ENGLAND, UK, GB, SCOTLAND, WALES
West Germany	GERMANY, GER, GFR, FRG	GERMANY, GER, FRG
France	FRANCE, FR, FRA	FRANCE, FR
Businesses	CO, LTD, COMP, INC, COMPANY, INCORP, INCORPORATED, INCORPORATION, CORPORATE, CORPORATION, ENTERPRISE(S), SA, CIE, SOCIETE, COMPAGNI, AG, GMBH	CO, LTD, COMP, INC, COMPANY, INCORP, INCORPORATED, CORP, CORPORATE, ENTERPRISE(S), SA, CIE, SOCIETE, COMPAGNI, AG, GMBH
Universities	UNIV, COLL, FACULTY, SCHOOL(S), ECOLE, UNIVERSITY(IES), UNI, SCH, COLLEGE(S), UNIVERSITAT, SCHULE, UNIVERSITE, WBH	UNIV, COLL, FACULTY, SCHOOL(S), ECOLE, UNIVERSITY(IES), UNI, SCH, COLLEGE(S), UNIVERSITAT, SCHULE, UNIVERSITE, WBH
Other	Other than business or university	Other than business or university

As you can see from this table, in the databases used in this investigation there are many different ways of representing the names and addresses of the authors' affiliated organizations. In particular, there were quite a few cases where we could not tell

from its name whether an organization was a business or a university. Consequently, you must be mindful of the fact that the "other" classification used in this study does not necessarily mean a public research organization. Also, these databases include conference proceedings, documents, and other materials that are not exactly research papers; although there is only a small number of these kinds of documents, this kind of problem must be taken into consideration.

As items of general consideration in doing statistical searches with the databases, the following points can be brought up:

1) The selection of research papers included in a database is greatly influenced by the compilation policies of the organization that created the database.

2) Of the papers published in Japanese scientific journals, normally only those with English summaries are included in the kinds of databases created by foreign organizations that were used in this study.

3) In international scientific journals, sometimes English-text papers written by Japanese people are rejected more because of linguistic problems than the quality of the content.

2. Database overview

(1) BIOSIS PREVIEWS

BIOSIS PREVIEWS, which we used for the purpose of getting a grasp on the numbers of research papers in the life sciences, contains articles from BIOSIS's major publications: "Biological Abstracts," "Biological Abstracts/RRM," and "Bio-Research Index." These publications are English-language information that comprehensively covers the world's research in the fields of biology and medicine. "Biological Abstracts" includes information on 260,000 research efforts, which is taken from about 9,000 major journals and monographs, every year. "Biological Abstracts/RRM" includes about 260,000 articles, e.g., reports, research information, etc., every year. Thus, the research papers, reports, and research information of over 9,000 kinds of publications from over 100 countries are the information sources for BIOSIS PREVIEWS. Over 6,048,000 items have been accumulated from 1969 to the present, August 1988.

The range of topics covers all fields in the life sciences, with the following fields at the center:

- Space biology
- Agriculture
- Anatomy
- Cytology
- Behavioral science
- Biochemistry
- Biological engineering
- Biophysics
- Biotechnology
- Botany
- Cell biology
- Clinical medicine
- Environmental biology
- Experimental medicine
- Genetics
- Immunology
- Microbiology
- Nutritional science
- Occupational health
- Parasitology
- Pathology
- Pharmacology
- Physiology
- Public health
- Radiobiology
- Cell biology
- Toxicology
- Veterinary science
- Virology
- Zoology

(2) INSPEC

We used INSPEC in searching for information about numbers of research papers in the fields of computer science and superconductors. The information included in INSPEC corresponds to the contents of "Physics Abstracts," Electrical and Electronics Abstracts," "Computer and Control Abstracts," and "IT Focus: Update on Information Technology." It forms the largest English-language database in the fields of physics, electrical engineering, electronic engineering, computers, control engineering, and information technology. Periodicals account for 78% of INSPEC's information sources; as of June 1987, over 3,900 periodicals have been examined as subjects. Of those, 730 periodicals contain abstracts for all of their articles. From 1977 to June 1987, there were 1,900,000 data items accumulated.

The range of subjects is broad, and the subjects are divided into four categories: physics, electrical and electronic engineering, computers and control, and information technology. The fields within each of those categories are as follows:

Physics (Subfile A)

- Acoustics
- Instrumentation and measurement
- Elementary particle physics
- Atomic and molecular physics
- Mathematics and mathematical physics
- General items
- Geophysics
- Physical chemistry
- Enriched materials: Structural, thermal, and mechanical characteristics
- Materials science
- Gas and fluid dynamics, plasmas
- Enriched materials: electrical, magnetic, and optical characteristics
- Nuclear physics
- Optics

Electrical and Electronic Engineering (Subfile B)

- Circuits and structural components
- Electromagnetic fields and waves
- Electronic equipment
- Power systems and applications

Computers and control (Subfile C)

- Computer hardware
- Control technology
- Software and applications
- Systems and control theory

Information Technology (Subfile D)

- Applications in business and industry
- Communications, calculations, and systems
- General and management applications
- Office automation

In this study, we used Subfile C (Computers and Control) when searching for information about the field of computer science; we used all of the files when searching for information about the field of superconductors.

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